UniPile 5.0 for Windows
User and Examples Manual

UniSoft Ltd.
Geotechnical Solutions

528 River Road
Ottawa, Ontario
Canada
K1V 1E9
www.unisoftltd.com

User Manual
Examples Manual

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FOREWORD

In broad terms, the **UniPile program** consists of three separate parts:

1. Pile capacity, which is analysis of the response of a single pile to applied load,
2. Simulation of the load-movement response for a static loading test, and
3. Settlement of a single pile or group of piles.

Part 1 involves the definition and input of pile and soil resistance parameters and the various loads and excavations affecting the resistance of the pile. The input can be by basic effective and total stress parameters and/or by CPT/CPTU soundings or SPT records. When defining the loads and excavations, their "Period" must be input, i.e. the "Initial" or "Final" conditions, where "Initial" refers to site conditions before work on the site begins and "Final" refers to site conditions after the work is completed and the piles are in operation. The analysis can be for either the "initial" or the "final". Loads and excavations do not need to be concentric with the pile, but can be defined for any X,Y-location, recognizing, for example, that a pile located in a marine environment will have not have the same resistance as a pile located further up the shore(because the effective stress distribution at the pile locations are likely different and pile resistance is directly related to the effective stress distribution). Part 1 output consists of Pile Capacity, Drag Force, location of the Neutral Plane, and Load Distribution, presented in tables and graphs.

Part 2 includes defining the pile load-movement relations by means of assigning t-z and q-z functions to the various soil layers. UniPile will let the User back-calculate the response of an actual test and establish the details of the load-movement response in terms of basic effective or total stress parameters. The simulation can be performed for a conventional head-down test or a bidirectional test. The latter feature is very useful in designing where best to locate the bidirectional cell level. Moreover, after a back-analysis of an actual bidirectional test, UniPile can convert the test results to an equivalent head-down test for assessment by conventional rules. The simulation includes adjustment for pile buoyant weight, water force, and the fact that the head-down test engages the softer soil layer first as opposed to the bidirectional test accessing the deeper located, stiffer layers first. Part 2 output consists of the load-movement results in tables and graphs.

Part 3 determines the settlement for a single pile or pile group based on the equivalent raft concept. The equivalent raft can be placed at the neutral plane, the pile toe, or at a user-defined depth, as well as have a user-defined shape. Stress distribution can be per 2(V)V:1(H), Boussinesq, or Westergaard methods. Part 3 output consists of settlement distribution of soil and pile in tables and graphs.

The **UniPile Manual** also consists of three parts.

Part I—"User Manual" explains the options and routines of the program. These explanations are also available from inside the program via the help function.

Part II—"Example Manual" presents several examples demonstrating the program applications including files of case analyses in selected papers by B.H. Fellenius. The intent is that a User on trying out the examples will quickly become versed in the use of UniPile. The software license includes technical support and UniSoft Ltd. will be pleased to reply to questions about the operations of the program.

First time User will find that working through Demo Example 1 will vastly shorten the time to become proficient in the use of UniPile.

UniPile 5.0 for Windows

User Manual

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Geotechnical Solutions

528 River Road
Ottawa, Ontario
Canada
K1V 1E9
www.unisoftltd.com

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PART I (Sections 1 through 6)

1.0 INTRODUCTION

1.1 Welcome

Welcome to UniPile 5.0 for Windows 7, a software for the design of piles and pile groups according to various design methods. UniPile produces analysis of pile capacity, pile settlement (single and group), negative skin friction, drag force, and downdrag along with aspects of drivability and residual load. It will also simulate the load-movement response of the pile in a static loading test—Head-Down and Bidirectional Cell.

The documentation for UniPile 5.0 comes in four separate documents:

1. This user manual to help you navigate the many features of the software.

2. A document entitled Getting Started describing how to setup, upgrade, register, and activate UniPile 5.0.

3. An examples manual describing the various example files provided with the software.

4. The "Red Book", a text book called "Basics of Foundation Design" by Bengt H. Fellenius, Dr. Tech., P.Eng., which addresses settlement analysis, piled foundations, footings, retaining walls, and vertical drain projects, supplementing (but not replacing) conventional and more comprehensive geotechnical textbooks. This document is not provided with the software, but may be downloaded free of charge by visiting: http://www.UniSoftltd.com/Uploaded/downloads/RedBook.pdf.

Important

The purpose of this user manual is not to teach or to educate engineers on the many concepts related to pile design and geotechnical engineering in general. We assume that our users are well experienced in the design of piles and deep foundation in general.

UniPile 5.0 is available in many modes: Demo, Educational, Basic, Standard, and Professional. Depending on the type of version you are running, some of the features described in this manual may be disabled. From time to time, we also issue updates to correct minor issues or add new features. Slight differences may exist between the images shown in this document and the version that is running on your computer.

This application has many features and hoping to learn them all in a single reading is unrealistic. Part I of this user manual refers to the use of the software in general terms. Part II describes the input variables used throughout the application.

If your copy of the software is already installed, activated, and ready to go, we suggest that you jump straight to Section 3.0 - Using UniPile. If you are anxious to perform an analysis immediately, jump to Section 4.0 - Your First Analysis.

1.2 Technical Support

Free limited technical support regarding the use of all our products may be obtained by contacting us at support@unisoftltd.com. We also suggest that you regularly consult our website at www.unisoftltd.com. It provides many technical papers and FAQs that may already have the answer to your question.

Before contacting us, please make sure that you are using the latest release of the product as we correct and release updates as issues are reported. Also, please have your serial number available. It is shown in the "About" window located under the main "Help" menu.

1.3 Recommended System Requirements

UniPile 5.0 was developed specifically for the Microsoft Windows 7 environment. It has however been tested on earlier versions of Microsoft Windows Vista, Windows XP (SP3), and Windows 2000.

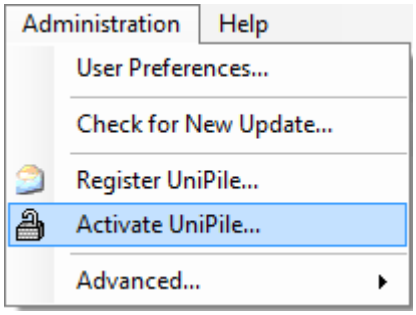
In that respect, UniPile 5.0 requires Microsoft.Net Framework Version 3.5 SP1 or above. Microsoft.Net Framework comes pre-installed with Microsoft Windows 7. For earlier versions of Microsoft Windows, you may be required to download and install Microsoft.Net Framework prior to resuming the installation of UniPile 5.0. Microsoft.Net Framework is a component developed and maintained by Microsoft Corp. It is free for all registered users of Microsoft Windows.

1.4 Example Files

If you selected this option during the setup process, a series of example files were installed in the "My Documents\UniPile 5.0\ Example Files" folder created under the current user documents folder. If the application was installed on a server, the network administrator will be required to move these files manually to provide access to all users. Alternatively, the same example files may be obtained by visiting the download section of our website atwww.unisoftltd.com.

1.5 Activating UniPile 5.0

All UniSoft products are copy-protected using activation code technology. When you purchased UniPile 5.0, you were provided with a unique serial number and activation code to unlock your copy of the software. Activation of your licence is performed via the "Activate ..." feature located under the main "Administration" menu.



Detailed information on how to register and activate UniPile 5.0 is available in our Getting Started document.

2.0 WHAT'S NEW

Now 32-bit
UniPile 5.0 is now a 32-bit compiled application. It is fully compatible with Microsoft Windows XP (SP3), Windows Vista and 2000, Windows 7, and Windows 8 (both 32-bit and 64-bit versions).

New input and results windows
We have developed a new look for all input and results windows. These were designed to simplify data entry and facilitate navigation between various components and results.

Janbu and conventional method
Pile and pile group settlement may now be calculated based on either Janbu or conventional parameters. Input conversion to Janbu parameters is no longer required.

Loads and excavations
Two new load types have been introduced: full and half embankments. Loads and excavation need no longer to be concentric with the pile analyzed, which allows designing for a more realistic environment.

Stress analysis
Calculation of stresses and settlements may now be performed using Boussinesq, Westergaard, or 2:1 stress distributions.

Pile resistance analysis
Pile ultimate resistance and load distribution may be calculated using:

(1) Static method (Beta or Alpha), CPTU-method (Eslami and Fellenius)

(2) CPT-methods (Schmertmann and Nottingham, deRuiter and Beringen, and Bustamente-LCPC)

(3) SPT N-indices methods (Meyerhof, Decourt, and O'Neill-Reese)
The results CPTU and CPT methods automatically show the equivalent ß-coefficients.

Bidirectional cell loading test simulation
In addition to the Head-Down static loading test, UniPile now also performs a Bidirectional-Cell loading test simulation.

Multiple t-z and q-z functions
Pile Resistance-Movement (t-z and q-z) functions for simulation of the static loading test include Ratio, Hyperbolic (Chin-Kondner), Exponential, Hansen 80%, Zhang, and a user defined model.

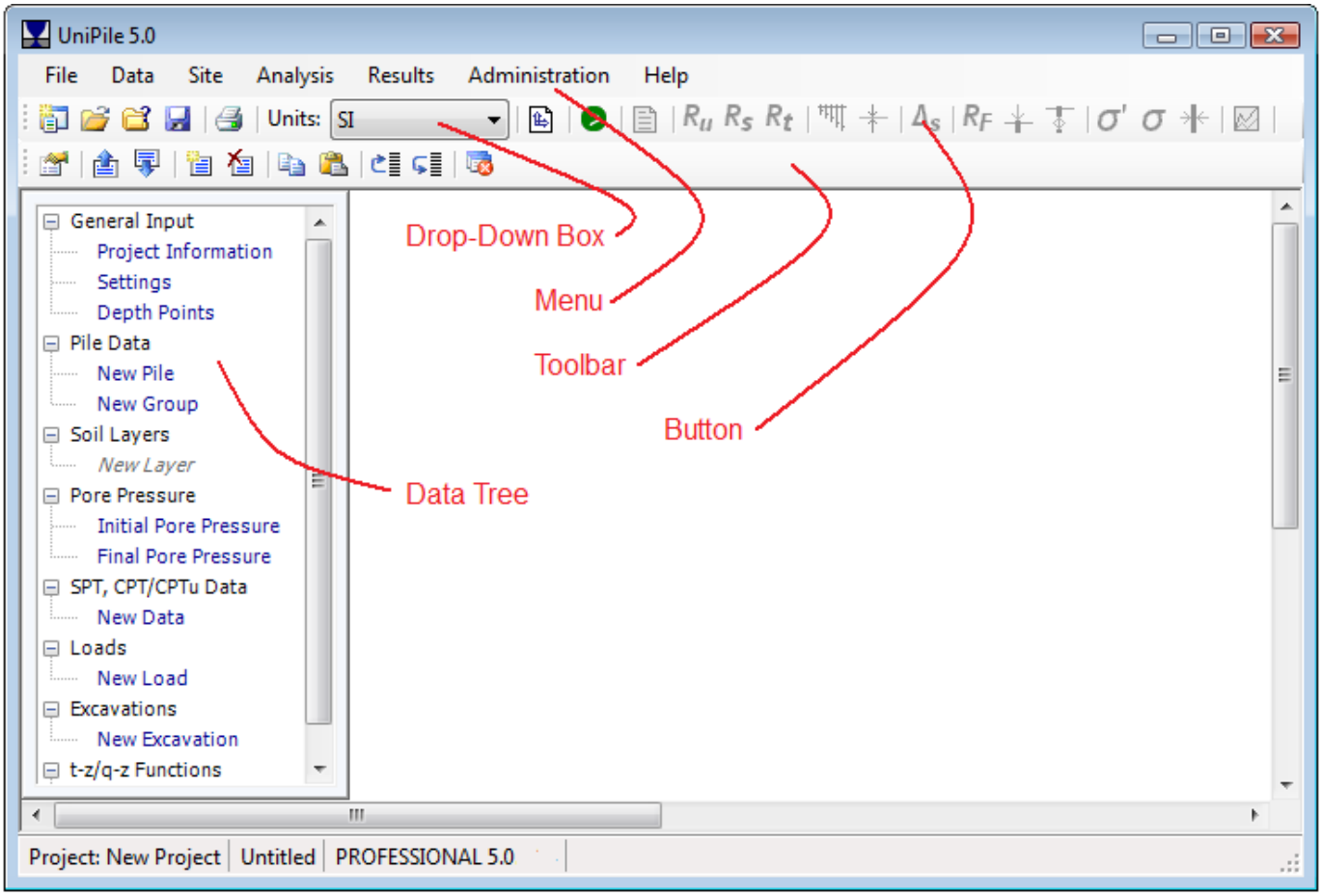
3.0 USING UNIPILE

We tried hard to ensure UniPile 5.0 is intuitive for most engineers. This section provides a quick overview of what you need to know before beginning.

3.1 Definitions

Using computer and software terms is no different than using geotechnical terms. Learning and using the correct ones on a consistent basis should help you learn to use our products faster. The following definitions are used throughout this manual.

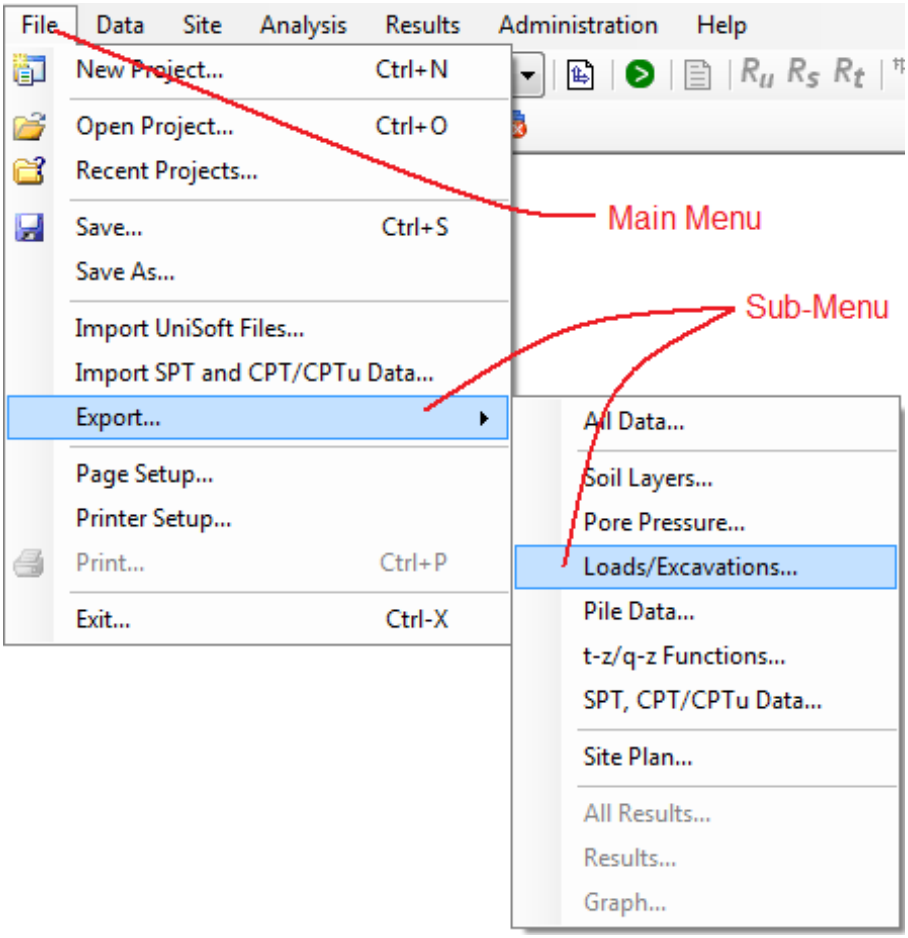
Interface
The interface is the means of communication between the user and the software. It is the sum of all the visible parts of the software. The image below represents UniPile 5.0's interface. It includes the main menu, buttons, and windows.



Toolbar
A toolbar is a graphic user interface component upon which menus, buttons, icons or other input or output elements are placed.

Menu and sub-menu

A menu is a list of commands usually presented at the top of the interface or at the top of individual windows. Menus are often hierarchically organized, allowing navigation through different levels of the menu structure. Selecting a menu entry should result in an action or provide another list of options. The latter is referred to as a sub-menu.



Popular menu items are often presented as buttons on toolbars. This saves the user time by allowing quick access to frequently-used actions.

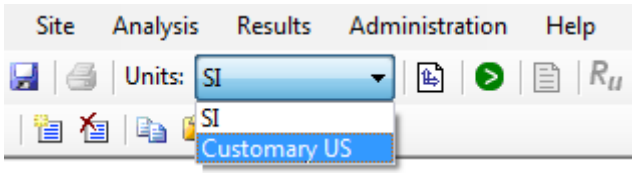
Button

In computing terms, a button is a user interface element that provides the user with a simple way to trigger an event. Selecting a button should result in an action or, in the case of a drop-down button, provide a list of available options. Buttons are often an iconic representation of the most popular menu options. They may also contain short text commands such as "OK", "Cancel", or "Proceed".

Buttons located on toolbars are usually a repeat of the most frequently used menu items.

Drop-down box

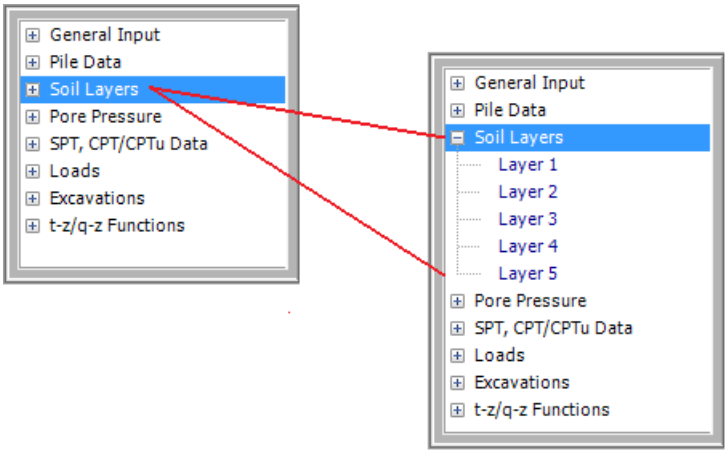
A drop-down box is a commonly-used graphical user-interface component. It may be a combination of a drop-down list or list box and a single-line textbox, allowing the user to either type a value directly into the control or choose from the list of items. In UniPile 5.0, design units are selected from a drop-down box displayed on the main toolbar.



Data tree

A data tree is a widely-used method to display inter-related data. It emulates a hierarchical tree structure with a set of linked nodes. In UniPile 5.0, a data tree is used to access every data form available. The main advantage of a data tree is that it makes information visible and readily available rather than having to navigate complicated menu structures. If you have used Microsoft Windows Explorer or Microsoft Windows Outlook in the past, you are likely very familiar with data trees.

One of the most powerful features of the data tree is that long lists of components may be individually collapsed or expanded by clicking on the + or - sign located on the left side of a heading.



The various features of the data tree used in UniPile are discussed in Section 3.2 - Navigating UniPile 5.0.

Windows or forms

In a Microsoft Windows compatible application, windows are used to display textual and graphical information. In UniPile 5.0, windows (or forms) are used to enter general data, soil properties, loads and excavations, display results, display messages, etc. This document assumes that you have prior experience with other Microsoft Windows products and that you are already familiar with the many features attached to windows such as opening, moving, resizing, and closing.

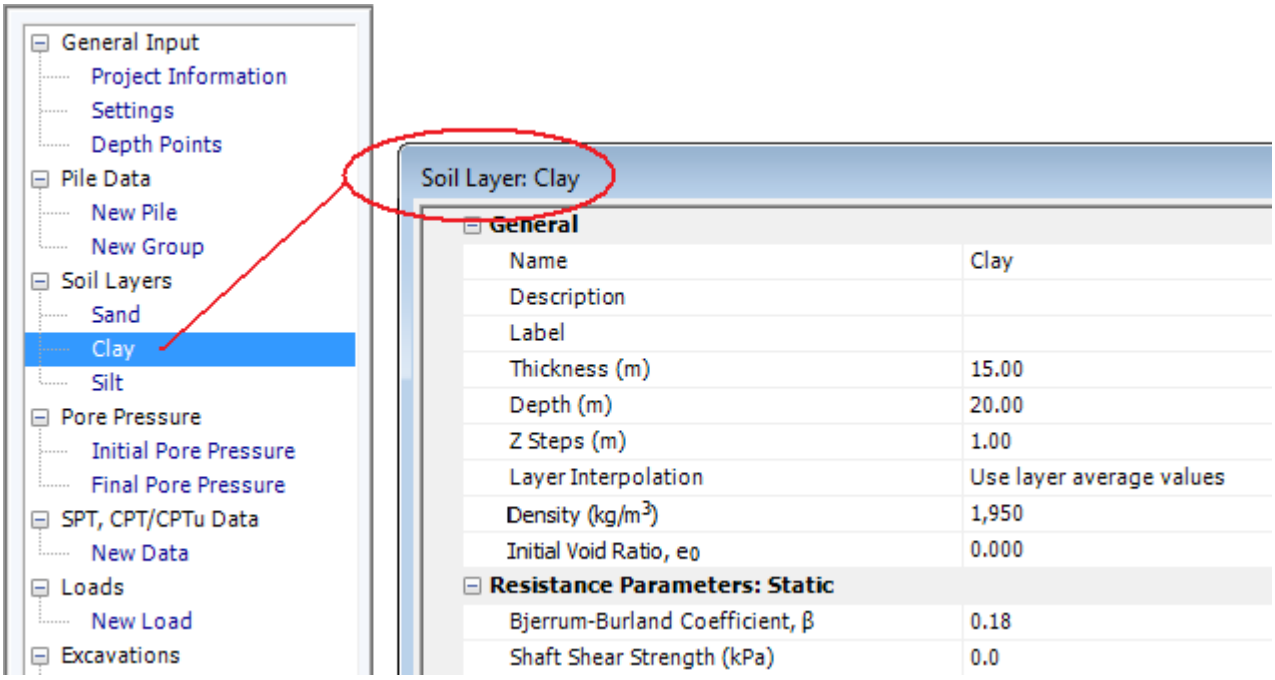
Component

This manual uses the term component to describe groups of data of the same type. For example, all soil layers are individual components of the same type. Loads and excavations are also components but of different types.

3.2 Navigating UniPile 5.0

In an effort to make the software more powerful and versatile, the navigation between various input windows is now performed via the main data tree. The data tree is a powerful tool as it allows the user to display and access a large number of items. The data tree is also context sensitive, a term meaning that the various menu options available at any given time might vary depending on the item currently selected.

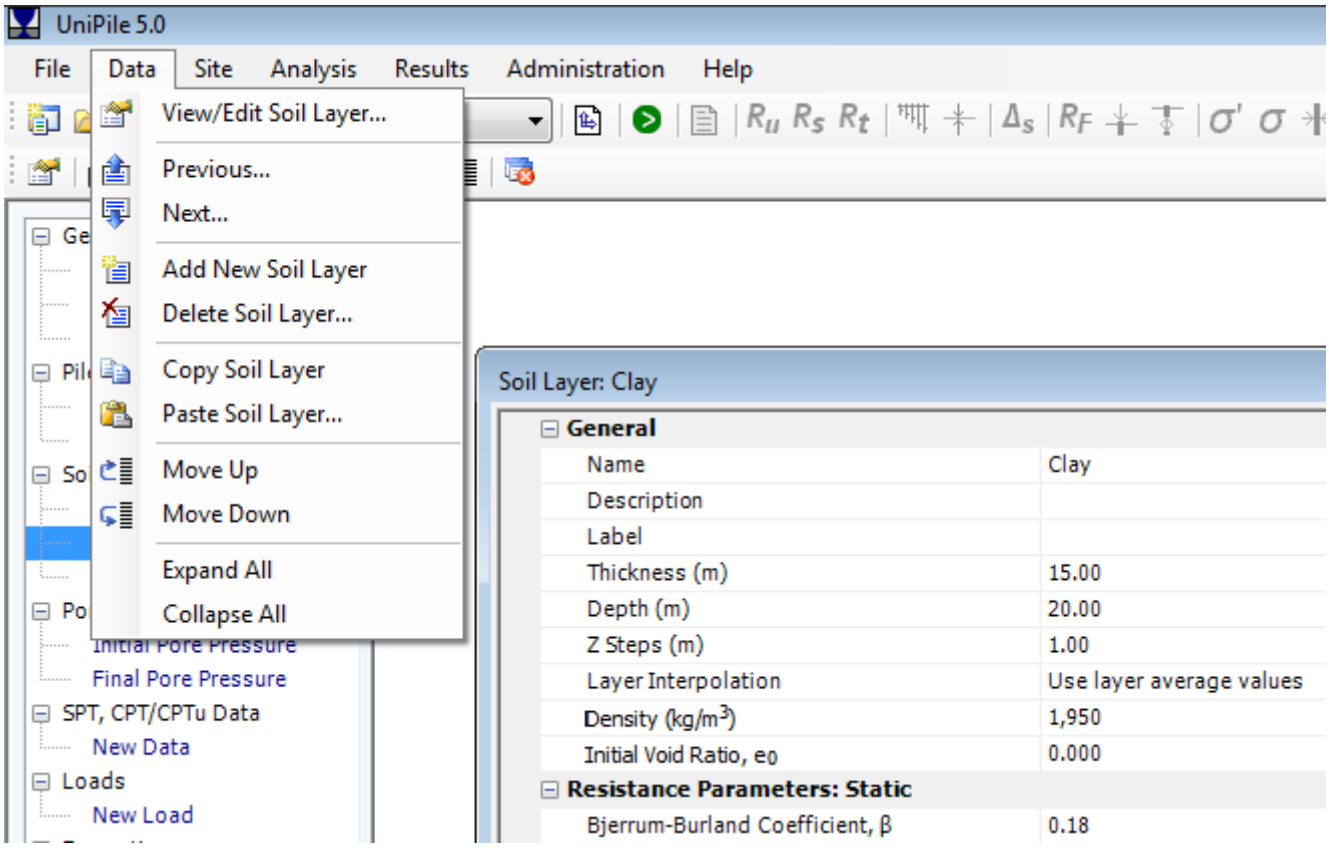
The following image shows the data tree for a project having three soil layers. Selecting any soil layer from the list (e.g., "Clay") will display the input data specific to the layer. Similarly, selecting any other item from a list will display the input data specific the item.



3.3 Data Menu

The main "Data" menu is used to add, delete, copy, paste, move, expand, and collapse the various components of the data tree. It is directly related to the context sensitive feature of the data tree. In other words, the options presented under the main "Data" menu are dynamic and will change according to the data tree item selected. This also means that the "Data" menu may be accessed directly by clicking the right mouse button on a selected data tree item.

The following sample image shows the list of options under the main "Data" menu when the "Clay" soil layer is selected. Many of the options presented under the main "Data" menu are also available as buttons on the secondary toolbar. The role of each feature is explained below.



The following section describes the various features of the "Data" menu, and assumes that a soil layer component has been selected. Some of these features may read differently or be disabled altogether if a different component is selected. However, the concept remains the same.

View/Edit Soil Layer
This option is the equivalent of a double click in a data tree item. It will bring the selected input window (or form) to the forefront of the interface.

Previous
Forces the selection of the item appearing just above the item currently selected. For example, if the second soil layer is currently selected, selecting this option will move the focus and display the input data related to the first soil layer.

Next
Forces the selection of the item appearing just below the item currently selected. For example, if the last soil layer is currently selected, selecting this option will move the focus to the "Initial Pore Pressure" item of the data tree.

Add New Soil Layer
Use this option to add a new component to the project. Depending on the current selection, this feature is also updated and used to add new soil layers, loads, excavations, or t-z/q-z functions. Components may only be added one at a time. Components are always added to the bottom of the list.

Tip

To insert a new soil layer between two existing layers, use the "Add New Soil Layer" option in conjunction with the "Move Up" command discussed below.

Delete Soil Layer

Use this option to delete an existing component of the project. Depending on the current selection, this feature may be used to delete an existing soil layer, load, excavation, or t-z/q-z function. Multiple components of the same group may be deleted at once. To select a series of components, click on the items while holding your keyboard Shift key. Use caution when deleting components. Once deleted, components cannot be retrieved via an undo command.

Tip

To de-select a group of items, simply release the Shift key and select any single item again.

Copy Soil Layer

Use this option to copy individual component data into the application memory. The data in memory may be pasted into another component of the same kind later. Depending on the current selection, this feature may only apply to soil layers, loads, excavations, and t-z/q-z functions. “Copy” is used in conjunction with the "Paste" command and has no use outside the application.

Paste Soil Layer

Use this option to apply the contents of the memory to a specific component of the same kind. Pasting data amounts to replacing the currently selected group of data with the data in memory. “Paste” is used in conjunction with the "Copy" command and is most useful to repeat the input of similar components.

Move Up / Move Down

Use these two commands to revise the order of the selected item inside the data tree. Moving soil layers up or down the list will affect the results as soil layers are assumed to be in the order in which they appear.

Tip

Use the "Move Up" command in conjunction with the "Add New Soil Layer" option to insert a new soil layer between two existing soil layers.

Expand All

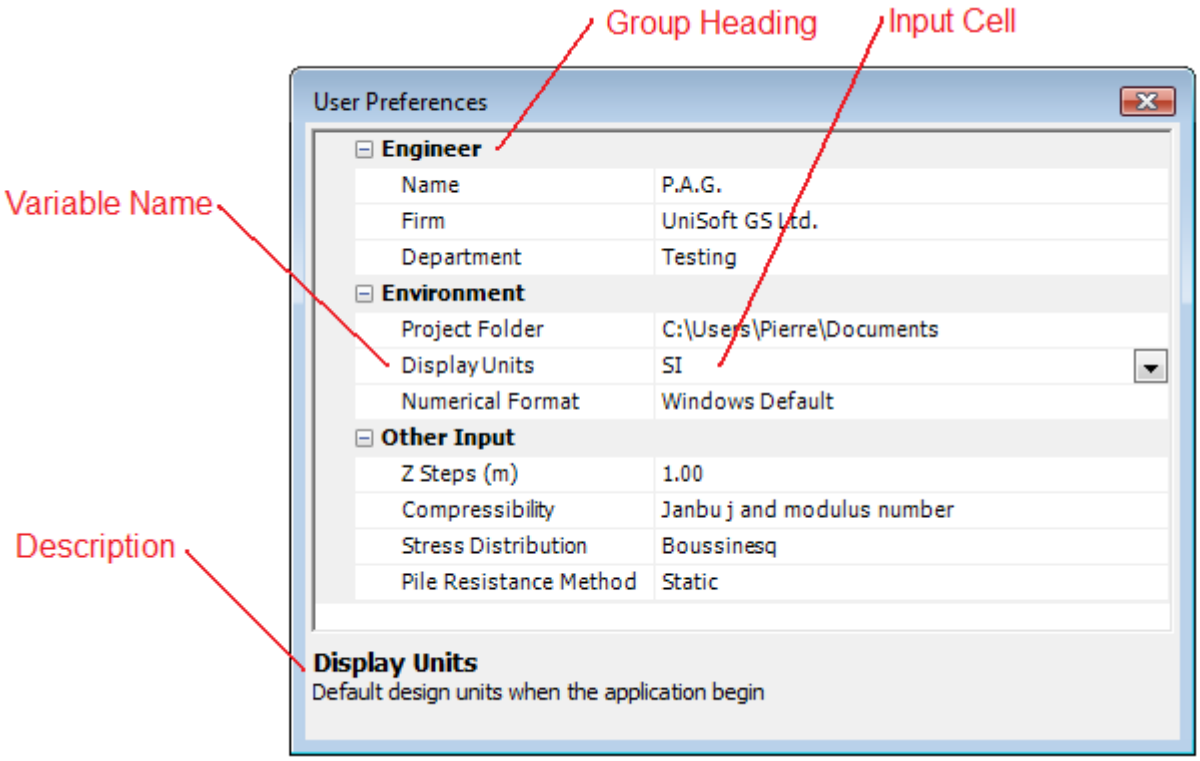
One of the best features of the data tree is that long lists of components may be individually collapsed or expanded by clicking on the + or - sign located on the left side of a heading. In addition, the complete tree may be expanded by selecting the "Expand All" command. Individual items may then be collapsed by clicking the - sign located on the left side of the heading.

Collapse All

This command acts opposite to the "Expand All" command. It collapses the entire tree to a minimum number of items. Individual items may then be expanded by clicking the + sign located on the left side of the heading.

3.4 Entering Data

In an effort to provide consistency and to facilitate the use of the software, all input windows use an Excel-type grid and cell system. The following image uses the "User Preferences" window to describe some of the features applicable to most input windows. User preferences may be accessed from the main "Administration" menu, and are discussed in greater detail in Section 17.0 - User Preferences.



Group heading
The group heading is used to describe a related set of input data. This heading is fixed and cannot be edited or changed. As with the data tree, group headings may be collapsed or expanded using the + or - signs located on the left.

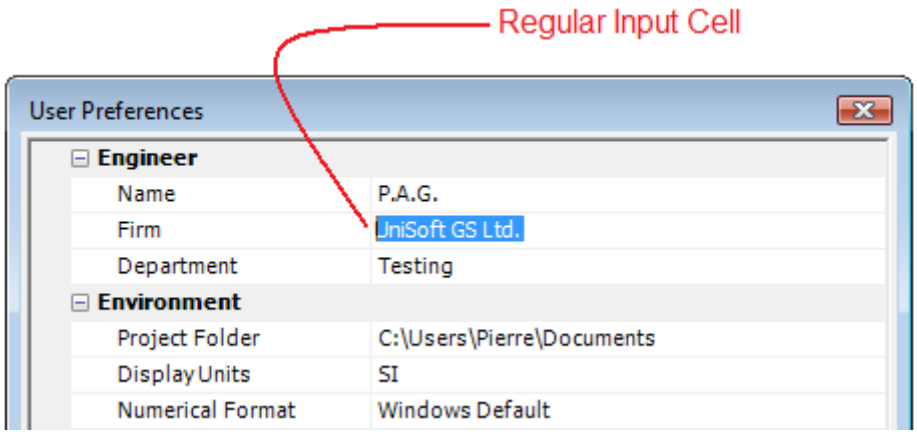
Variable name
The variable name is a short reference to the specific variable under consideration. When selecting a row, the specific variable and a short definition will appear at the bottom of the window. The variable name is fixed and cannot be edited or changed.

Description
The bottom of the window provides a short definition and relevant information regarding the variable under consideration. This description is fixed and cannot be edited or changed.

Input cells
Input cells are on the right side of each variable name. There are 3 types of input cells: regular, drop-down, and button. Once selected, input cells behave differently depending on their type. Navigation between input cells is performed using the mouse cursor or the keyboard's Up or Down arrow keys.

Regular input cell

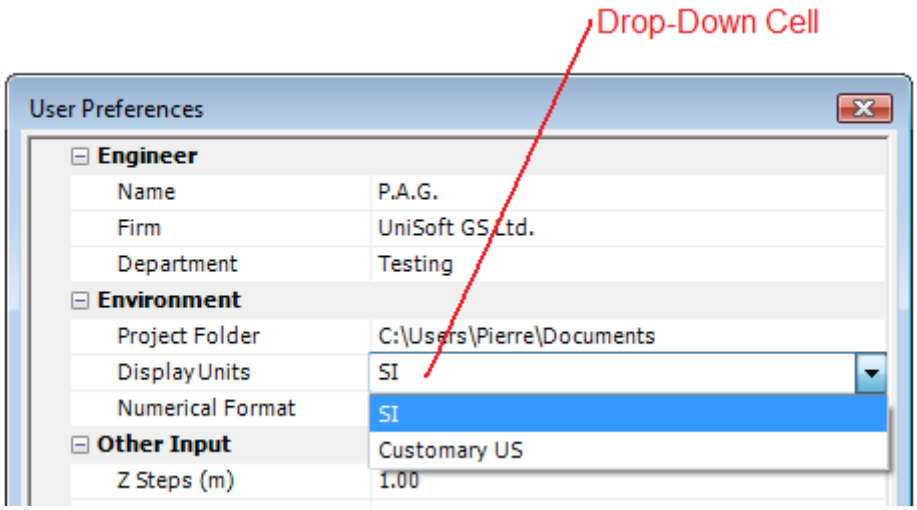
This is the most common type of input cell used throughout the application. It was designed to behave as a Microsoft Excel spreadsheet cell. Once it has been selected, the cell may be edited by typing, pressing the keyboard's F2 key, or double-clicking the left mouse button. Editing is cancelled using the keyboard's Esc key or recorded by pressing the keyboard's Enter key or moving to another cell.



Drop-down input cell

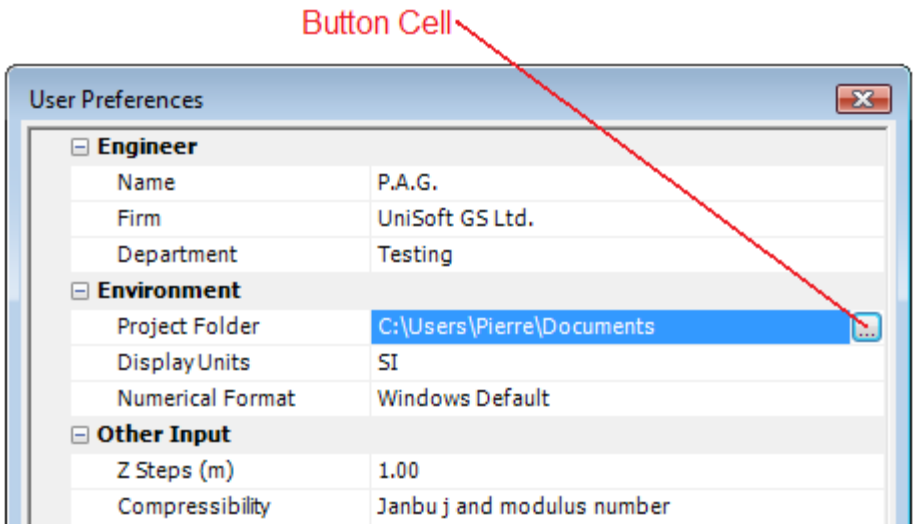
A drop-down input cell is recognized by the downward arrow (a triangle with its apex pointing downward) located on the right side of the cell. It usually provides the user with a list of items to choose from. This type of cell is edited by pressing the keyboard's F2 key or by clicking the left mouse button on the downward arrow. Editing is cancelled using the keyboard's Esc key or recorded by pressing the keyboard's Enter key. Some drop-down input cells will only allow selection from a pre-determined list. Others will allow you to enter and select your own content.

An example of a drop-down input cell may be found in the "Display Units" input located in the "User Preferences" window.



Button input cell

When it has the focus, a button input cell is recognized by the ellipsis button (...) located on the right side of the cell. When activated, this feature will provide a new input window, allowing you to complete the editing. This type of cell may be edited by pressing the keyboard's F2 key or by clicking the left mouse button on the ellipsis button.



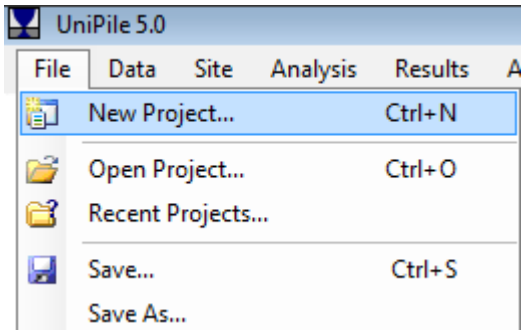
The "Project Folder" input located in the "User Preferences" window is an example of a button input cell. When selected, it will display a browser window which allows the user to select the folder of his/her choice.

4.0 YOUR FIRST ANALYSIS

If you have read the previous sections of this document, you should now be up and running and have a better understanding of the interface. However, you still have not used the software for its intended purposes. This section will guide you through the steps necessary to perform your first analysis.

4.1 New Project

When starting a new project, we recommend that you access the "New Project" command located under the main "File" menu. Doing so will reset your entire application to the original defaults. On engaging this feature, if the current file was is modified and not yet saved, you will be offered the option to save, skip or cancel.



When selecting a new project, your interface will revert back to the original defaults and preferences. Some of these preferences may be customized to your specific needs. In order to do this, access the "User Preferences" command located under the main "Administration" menu..

4.2 Using the Demo Examples

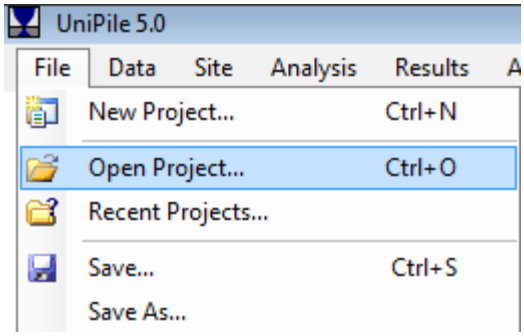
As part of the setup process, you had the option of installing a series of example files that may be used for educational purposes. If you elected to do this, these example files were installed in the "UniPile 5.0 Example Files" folder created under the current user document folder. If the application was installed on a server, the network administrator may need to move these files manually to provide you with access.

The examples provided with the application were designed to cover a large range of conditions. Note that if you are using a Demo version, you will not be able to save and will be limited with what you may change. Nonetheless, the example files are a great tool which will assist you in learning the various features of the software as well as many geotechnical concepts.

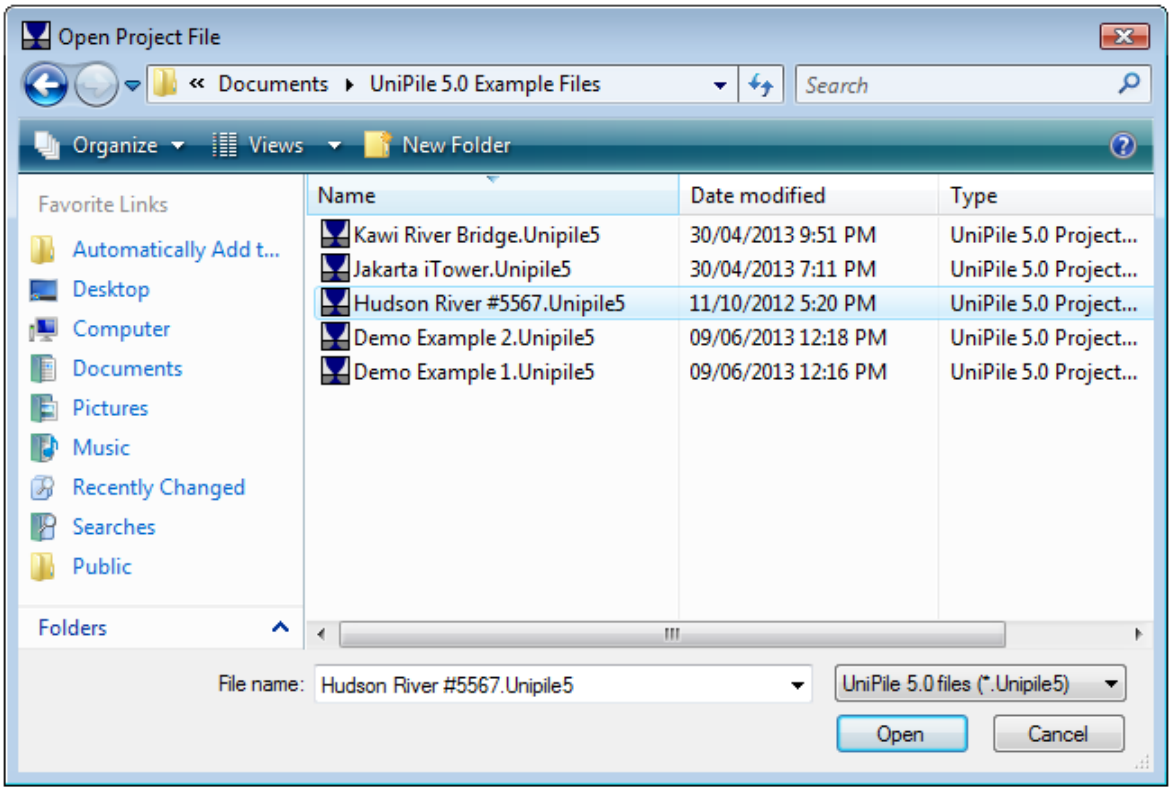
Alternatively, if these example files were not installed as part of the original setup, you may obtain them by visiting the download section of our website at www.unisoftltd.com.

4.3 Open Project

To open a new project already residing on your system, access the "Open Project" command located under the main "File" menu.



A browser window showing the contents of your computer and other connected drives should appear. UniPile 5.0 project files have by default the .UniPile5 file extension. Once you find the project you are looking for, simply bring it in by clicking the "Open" button.



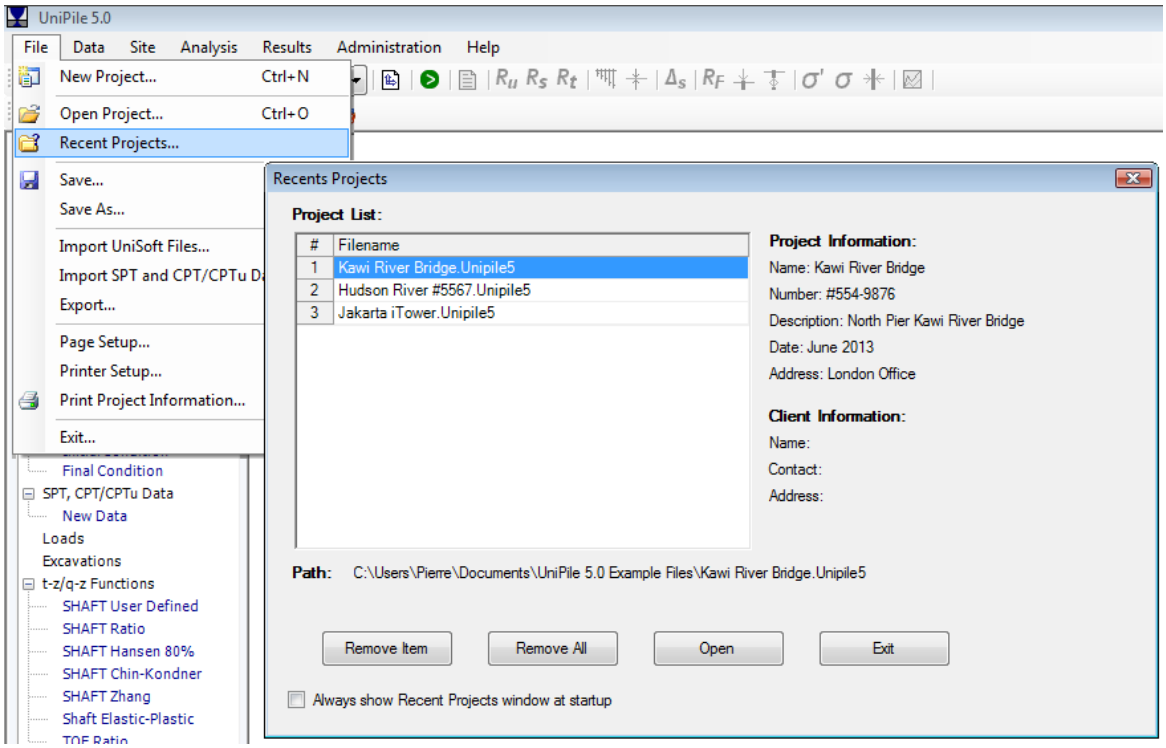
If the process was successful, the interface and the data tree will automatically be updated to display the latest set of data of the imported file.

Important
In many versions of Windows, file extensions are hidden by default. If this occurs, you may not be able to correctly identify UniPile 5.0 project files. If this is the case, we recommend that you contact your network administrator.

Important
Only project files previously created with UniPile 5.0 may be opened in this fashion. If you are a registered user of UniPile 4.0, you may import UniPile 4.0 project files (.unp) using the "Import" feature. Importing other file formats is discussed in Section 5.0 - Importing and Exporting.

4.4 Recent Projects

Project files may also be accessed via the "Recent Projects" feature located under the main "File" menu.



UniPile 5.0 records and keeps a list of the projects previously worked on (up to 25). One of the advantages of this feature is that it provides you with more information than simply a file name. For a selected project file, it will display project and client information such as name, number, description, contact, address, and the full path of the project file in your system. The bulk of the information displayed in this window is obtained from the "Project Information" window which is discussed in Section 7.0 - Project Information.

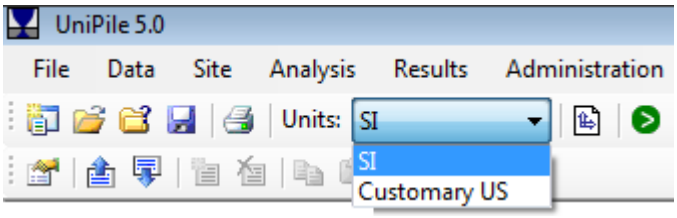
The "Remove Item" and "Remove All" options allow you to delete and maintain the project list. Selecting "Open" will open the selected project in UniPile.

The list of projects is unique to each user account. Opening a project on an instance of the application on your laptop would not affect the list of projects on an other instance of the application.

Important
Although a project may appear on the list, it may not be available for you to open. Such would be the case if the file has been renamed, moved, or deleted or if the file was located on a separate drive or server that is currently unavailable.

4.5 Selecting Units

The first action one typically completes before entering data is selecting the system of units. With UniPile 5.0, this feature consists of a drop-down box conveniently placed in the main tool bar.

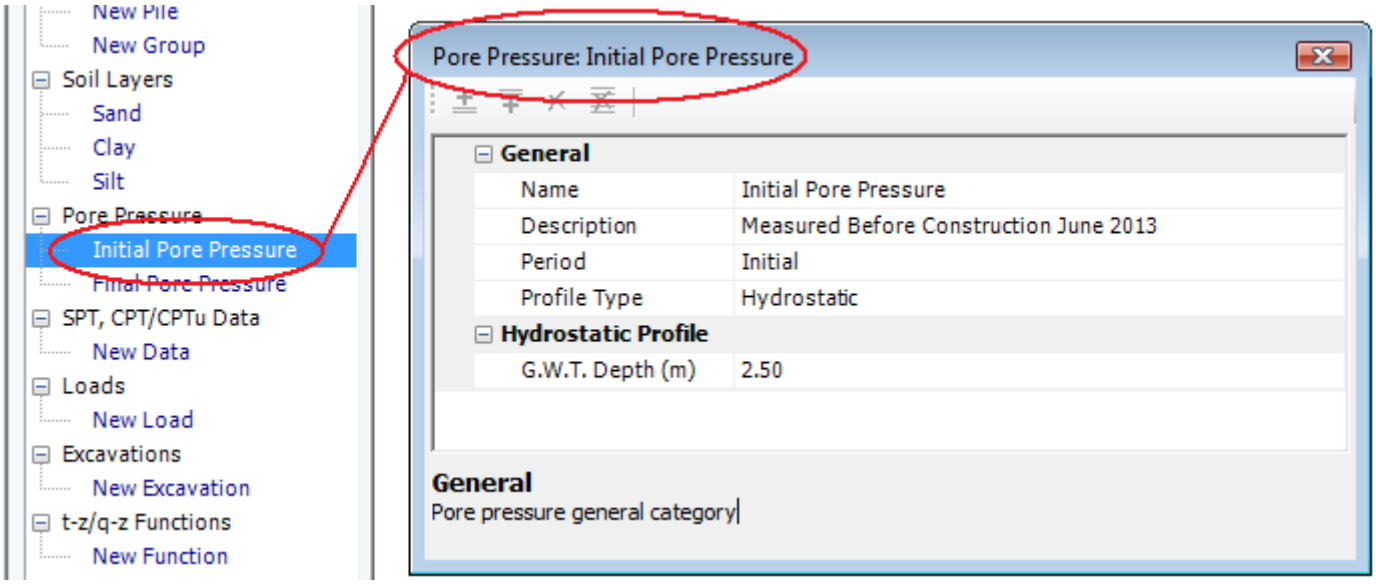


Two systems of units are available: The International System of Units (SI) and the US Customary Units. One of the best features of UniPile 5.0 is that the system of units may be switched on the fly at any time. This applies to both the data and the results. For example, some of the input may be made in SI-units, while others may be input in US Customary Units(after switching to US units). Once the analysis is concluded, the results and charts may be converted back-and-forth between either system with a single click.

Important
To avoid leakage errors due to multiple conversions effected on the same data, UniPile performs what is known as hard conversion. This means that data are converted, kept in memory, saved, and calculated with a high level of precision. However, when displayed on screen, they may be subjected to rounding to a lower level of precision. For example, entering a 10-foot thick soil layer would be internally converted to 3.048 metres; however, it would be rounded to 3.05 metres when displayed.

4.6 Viewing Design Data

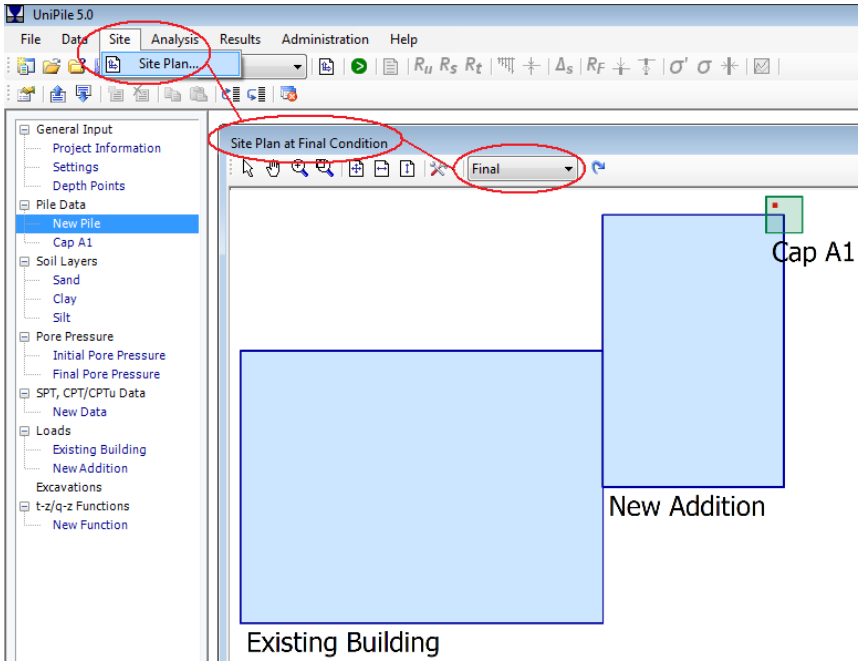
Also new to UniPile 5.0 is the way in which design data are accessed and presented. No longer are they hidden under a series of menus. All input windows relating to your current project are listed in the data tree located on the left side of the interface. For example, to view the input window for the Initial Pore Pressure, simply click the related entry from the data tree.



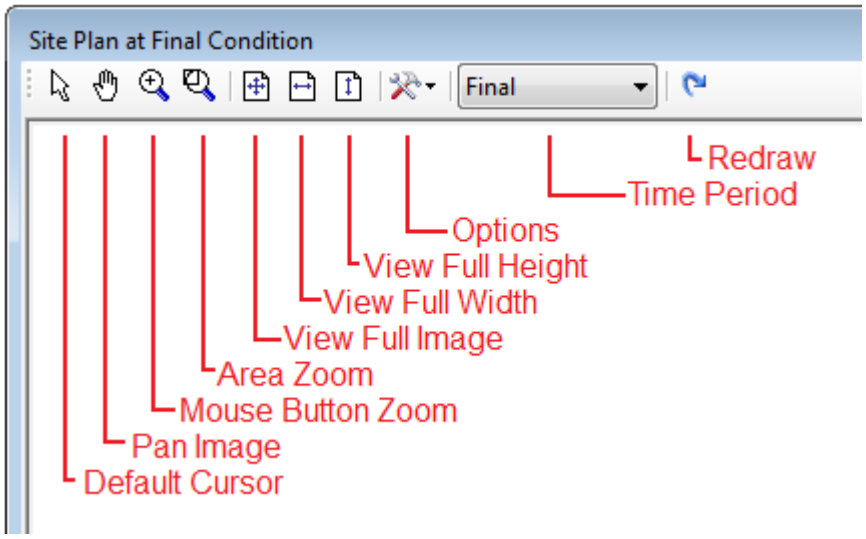
The data tree combined with the "Data" menu provide an efficient way to navigate, edit, add, and delete input data. Refer to Section 3.0 - Using UniPile for more information regarding various features of the data tree.

4.7 View Site Plan

When dealing with multiple coordinates, even small mistakes may result in the most severe consequences. In order to assist the engineer, a bird's eye view of the site under consideration is produced by accessing the main "Site Plan" menu. In addition, the site plan may be printed or exported to a bitmap file. Additional information may be found in Section 4.12 - Print Data and Results and Section 5.6 - Export Site Plan to Bitmap.



The site plan window has its own toolbar displaying a series of options used to customize the view. Some of these options are used to modify the behaviour of the cursor, or to change the scale and the extent of the drawing, while others are used to customize the contents of the drawing. These options are described and discussed below.



Default cursor
Many of the options associated with the site plan will change the way the cursor reacts when moved over the image. Use this button to return the cursor back to its default state and reset other features.

Pan image
Panning (in computer terms) enables you to move the image both horizontally and vertically by holding down the left mouse button. Panning is equivalent to moving the image using the vertical and horizontal scroll bars located at the right and bottom of the view. Select the default cursor button to return it to its default behaviour.

Important
Panning may only work when the image has previously been zoomed and the extent of the image is beyond the edge of the view.

Mouse button zoom
When enabled, it allows the user to zoom in or out of the image by clicking on the left or right mouse buttons, respectively. Select the default cursor button to return it to its default behaviour.

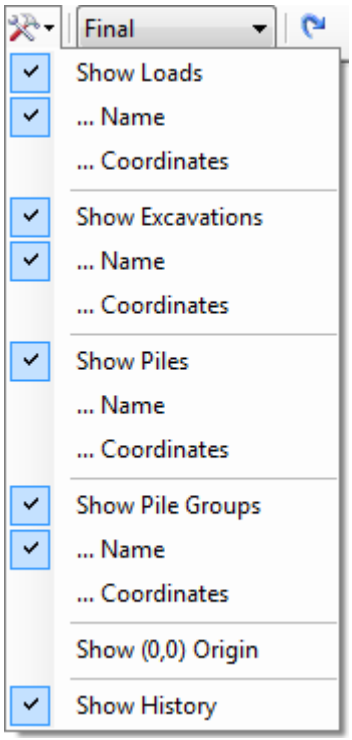
Area zoom
When selected, this option allows you to zoom the image in a specific rectangular area. To do this, move the cursor to one corner of the area you want to enlarge. While holding down the left mouse button, move the cursor to create a rectangle around the area you wish to enlarge. Release the mouse button. Select the default cursor button to return it to its default behaviour.

View full image
Resets the image zoom so the full image (the width and the height) fits inside the current view.

View full width
Resets the image zoom so the width fits inside the current view.

View full height
Resets the image zoom so the height fits inside the current view.

Site plan options
This is a drop-down button which allows you to dictate the contents of the site plan. Specific items may be selected (checked) or de-selected (unchecked).



Use these options to hide or display the loads, excavations, mesh points, their coordinates, the (0,0) origin, or the construction history via the "Show History" option.

Time period
This feature allows you to show the various site conditions at initial and final condition. Assuming that various loads and excavations were set to apply at various time periods, you may use this option to display only the components applicable up to that time period.

Important
This feature works in conjunction with the "Show History" option located under the "Site plan options". When "Show History" is selected, the loads and excavations displayed will be those applicable up to the selected period (i.e. inclusive). When de-selected, the loads and excavations displayed will only be those applicable to the selected period (i.e. exclusive).

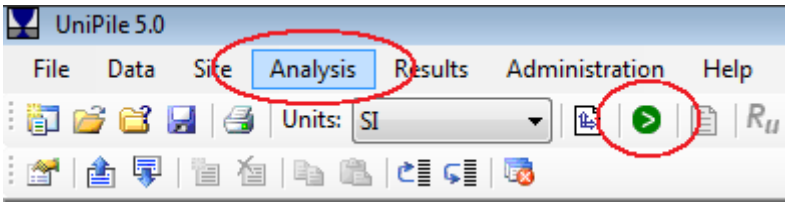
Redraw
Use this feature to redraw the site plan. This is a rapid way to reset the drawing to its full view.

Tip
By default, loads appear in light blue while excavations appear in light red with a certain level of transparency. This feature results in overlapping loads and excavations of a darker tone.

4.8 Perform an Analysis

Technically, if you have just created a new project and have not yet entered any data or information, you should still be able to perform an analysis. If this is the case, you will be presented with a complete set of results indicating 0. For the purposes of learning UniPile however, it is recommended that you open one of the example projects installed at setup.

Your first analysis is initiated by accessing the "Analyze" command located under the main "Analysis" menu.

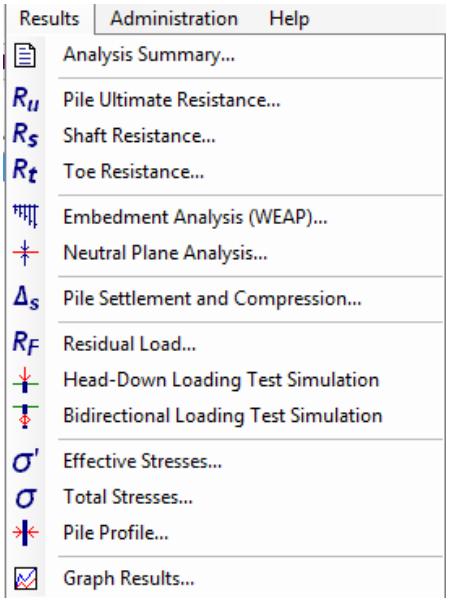


The time required to complete the analysis depends on multiple factors, including the speed of your processor, the depth of the soil profile, the number and size of the loads and excavations, and the many options selected.

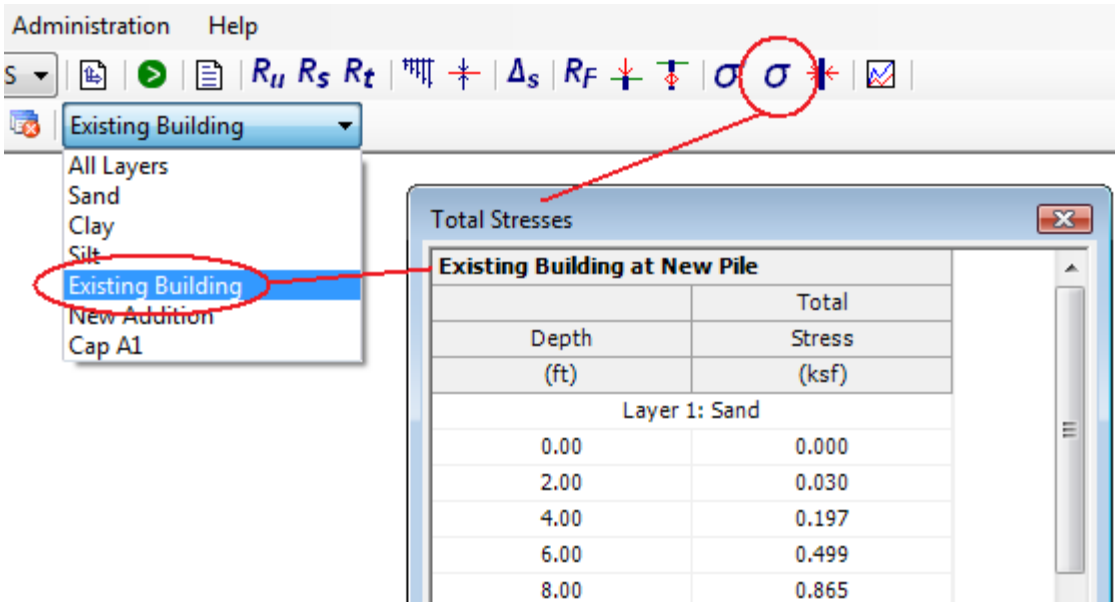
After a few projects, you will learn to negotiate and compromise between pushing the application to its limits versus using the time necessary to perform complicated analyses.

4.9 Review Results

If your analysis was successfully completed, you will be presented with a results table displaying the total compression of each soil layer. Other results may be displayed by accessing the main "Results" menu.



Additionally, the secondary toolbar may be updated with a series of drop-down boxes meant to display other sets of results applying to the same topic. The image presented above displays the options available when the total stresses results are displayed. Use the drop-down boxes to change the set of results on the fly.



All results produced by UniPile may be exported as a group to an Excel file or as individual results to an ASCII text file for further editing and manipulation. Refer to Section 5.0 - Importing and Exporting for more details on how to export results.

The Professional version of UniPile produces 13 different results topics. These are discussed below. Most results may also be displayed in chart format. The features affecting the charts are discussed in Section 4.10 - Chart Results.

Analysis Summary
This is a quick overview of the pile resistance and settlement obtained as a result of the analysis.

Pile Ultimate Resistance, R_u
This table reports on the pile ultimate (shaft and toe) resistance—pile capacity.

Shaft Resistance, R_s
Report a breakdown of the many parameters used in the calculation of the shaft resistance. The extent of this table depends on the selected pile resistance method.

Toe Resistance, R_t
Present a breakdown of the many parameters used in the calculation of the toe resistance. The extent of this table depends on the selected pile resistance method.

Embedment Analysis (WEAP)
Present the results of a static soil resistance for an array of depths. Typically these results may be exported to Excel or a text file to facilitate input into the GRLWEAP software.

Neutral Plane Analysis
Report on the pile factor of safety and the depth of the neutral plane for an array of dead load.

Pile Settlement and Compression
Present the calculations of the expected long-term pile compression and consolidation settlement (in the vicinity of the pile) caused by the pile group. This analysis assumes equilibrium (i.e. no pile/soil differential settlement) at the location of the neutral plane.

Residual Load
Report on the residual load profile calculated from the % of shaft and toe mobilization specified. If enabled, the false resistance will be included in the loading test simulation.

Head-Down Loading Test Simulation
Report on the load-movement curve simulating a head-down static loading test to soil failure. This simulation is based on the t-z/q-z curves describing the stress-movement behaviour of the soil along the pile shaft and at the toe of the pile.

Bidirectional Loading Test Simulation
Report on the load-movement curve simulating the Bidirectional Cell) static loading test. This simulation is based on the t-z/q-z curves describing the stress-movement response of the soil along the pile shaft and at the pile toe.

Effective Stresses
Effective stress provides a compilation of the total stress, pore pressure, and effective stresses used in the analysis.

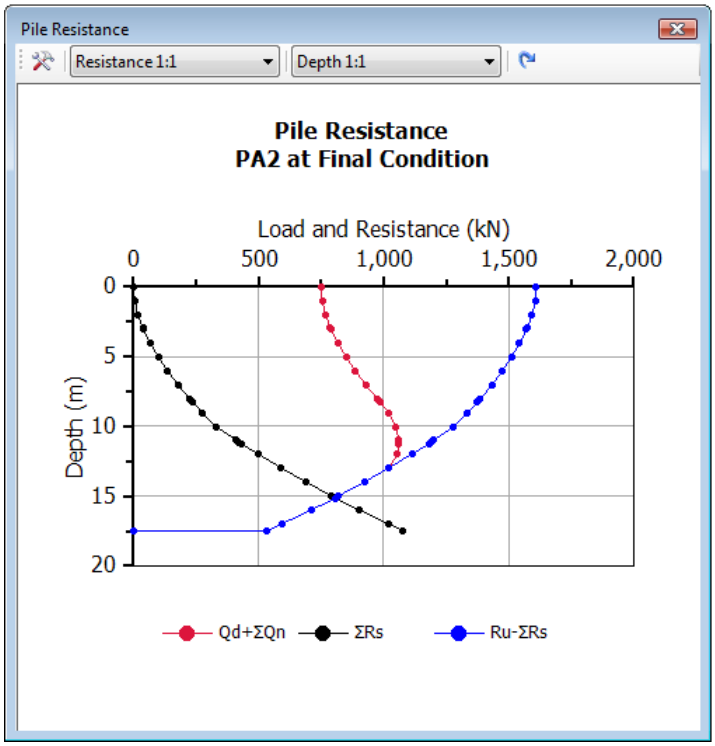
Total Stresses
Total stress provides a breakdown compilation of the stresses for a specific component. The results may be modified to display the stresses caused by a specific soil layer, load, or excavation.

Pile Profile
This table represents the various pile properties used throughout the analysis.

4.10 Chart Results

Most results can be presented in chart format. This provides a good way to quickly demonstrate the behaviour and tendency of the results. The results displayed can be charted by accessing the "Chart Results" option located under the main "Results" menu. In addition, all charts may be printed or exported to a bitmap file.

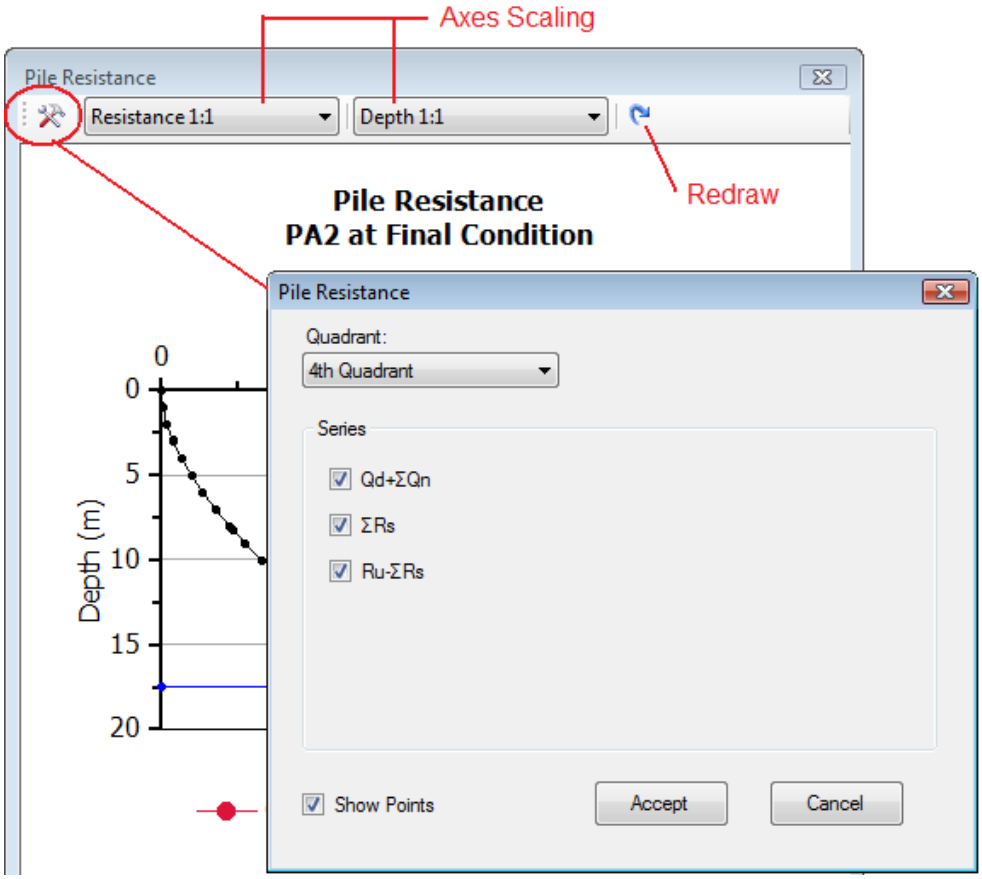
The image below shows a graphic representation of the pile ultimate resistance.



Note

Charting has been included in UniPile as a matter of convenience. Charting data may be exported to a separate text file to allow for more advanced charting and result manipulation by means of graphics software, e.g., Excel.

The chart window has its own toolbar displaying a series of options used to customize the view. Some of these options are used to modify the contents of the display, others to change the scaling of the axes. Changing the options for one chart will not affect the charts for other topics. Options are described below.



Quadrant
Select this option to change the quadrant.

Series
Use this option to add or remove a specific series from the chart. The series in this list vary depending on the type of results displayed on the screen.

Show points
Select this option to toggle chart points ON/OFF.

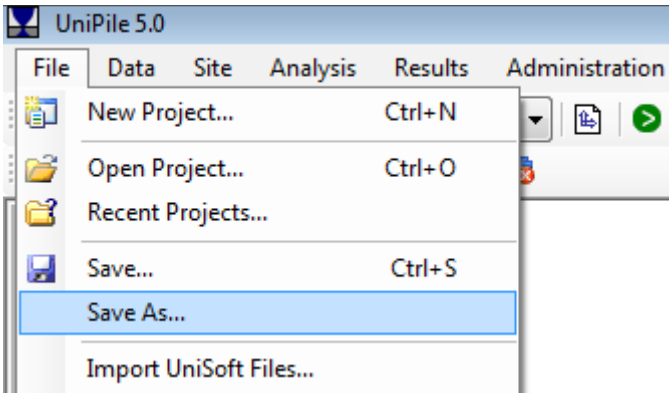
Axes scaling
Use this option to customize the scale used for each axis. When accessing this feature, a scroll bar will be displayed, allowing you to move the visible extent of the data.

Reset Axes Scale
Use this option to quickly reset the axes scale to 1:1.

Important
Although multiple results windows may be displayed onscreen simultaneously, only the top results window (with the focus) may be charted.

4.11 Save Data

The input data are saved by accessing the "Save" or "Save As" command located under the main "File" menu.

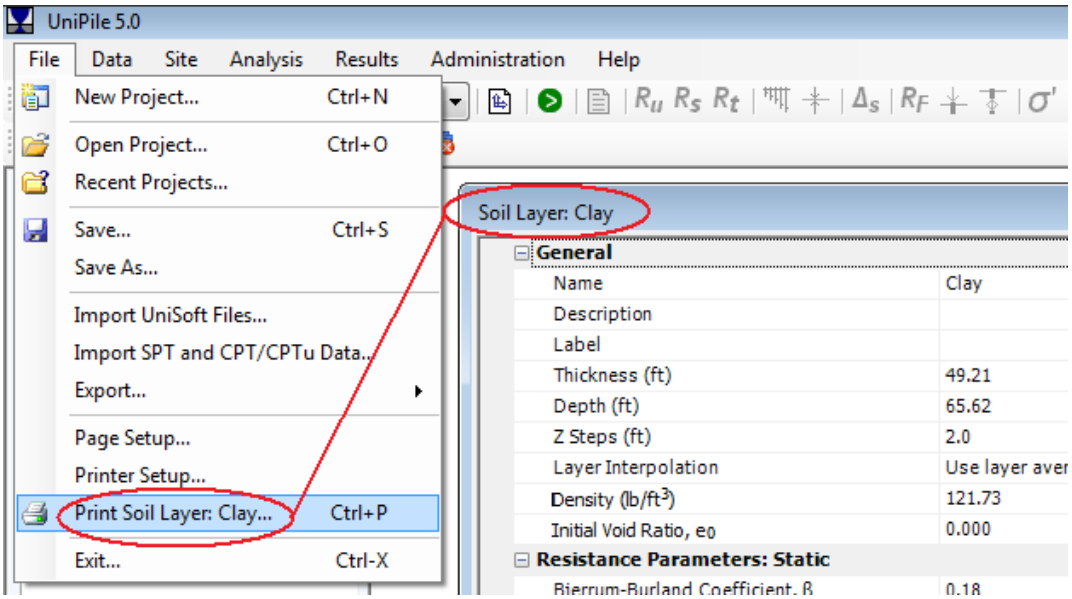


When selecting "Save As", you will always be presented with an environment window giving you the option to browse and save your data using the filename and folder of your choice. If your data were previously saved (or opened) under a given name, the "Save" option will skip the environment window and save the file in the background.

Important
The "Save" and "Open" options may only be used to open and save project files (i.e. files with the ".UniPile5" extension). Other types of data may be imported or exported using the import and export features discussed in Section 5.0 - Importing and Exporting.

4.12 Print Data and Results

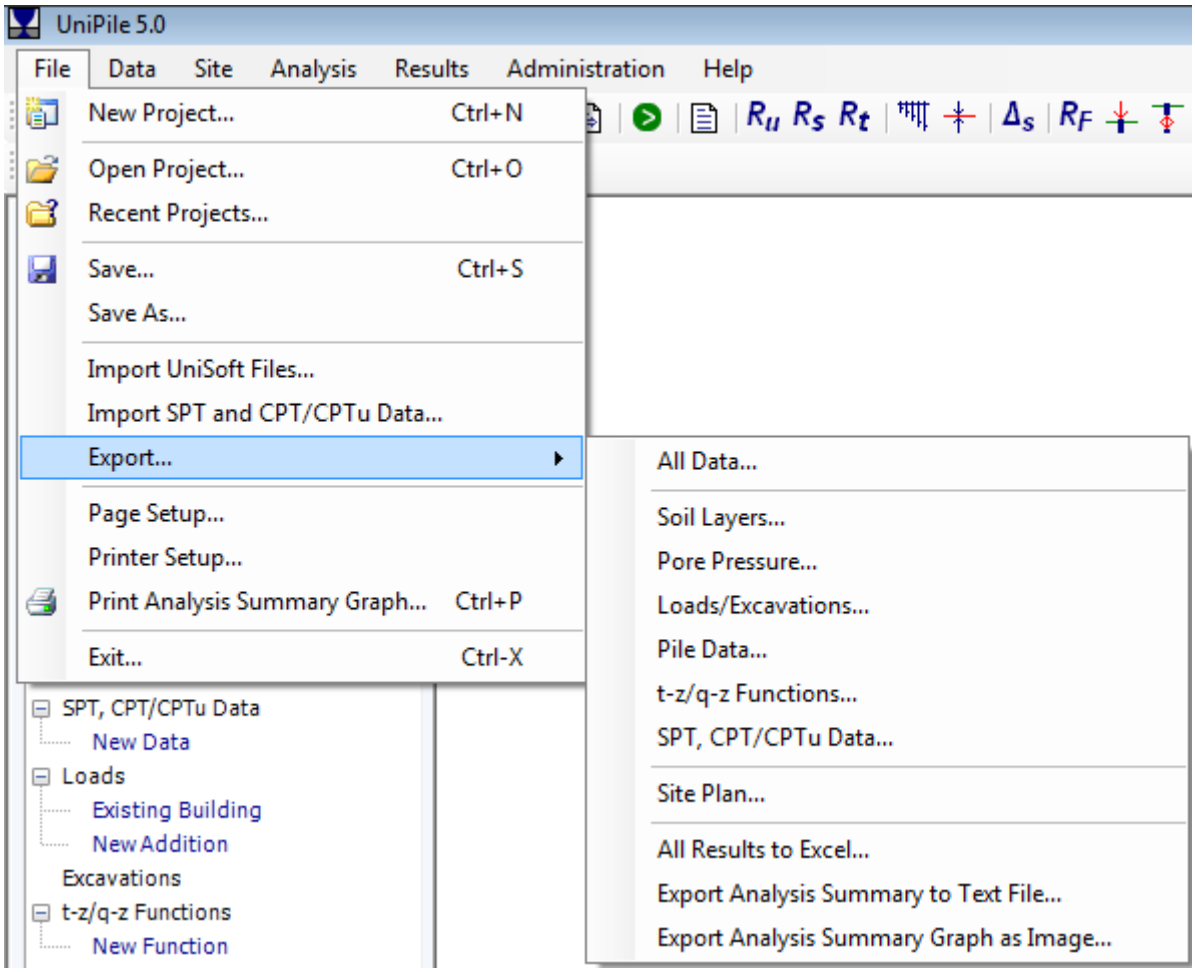
All data, results, and charts produced by UniPile may be sent to a Microsoft Windows 7 compatible printer. Printing in UniPile is context sensitive, meaning that only the data or results currently on top (with the focus) may be printed. The image below shows the input data for a Clay soil layer. The "Print" option is updated to show the specific topic available for printing at this time.



Basic page setup, including paper size, source, orientation, and margins is available via the "Page Setup" option. UniPile also provides the ability to print to a PDF file directly. This may also be achieved by downloading and installing one of the many PDF printers available on the Internet.

5.0 IMPORTING AND EXPORTING

Importing and exporting features extend the usefulness of UniPile to other popular software. The exporting and importing options are located under the main "File" menu, and are described below.



5.1 Importing UniPile 4.0 Files

Project files (.unp), soil files (.sol), and load files (.lod) created with UniPile 4.0 may be imported directly into UniPile 5.0. Importing these types of files is very similar to opening a project file. When selected, a window will appear allowing you to browse the contents of your computer and other connected drives. Once you find the file you are looking for, simply bring it in by clicking the "Open" button. If the process was successful, you may be prompted with the option to overwrite or append the contents of the file to the data currently in memory. The data tree will automatically be updated to display the latest set of data.

5.2 Importing UniSoft XMLU Files

The UniPile 5.0 user has the ability to import XMLU files. Although very specific to UniPile 5.0 and other UniSoft applications, the XMLU file format is based on the popular extensible mark-up language (XML). In short, XML is a set of rules for encoding documents in machine-readable form.

When used in conjunction with the exporting features of UniPile, soil layers, pore pressure profiles, loads, and excavation data may be imported into an existing project. This powerful feature of the software allows you to quickly combine data from one project with another. It may also be used to build a library of soil profiles, loads, excavations, or t-z/q-z functions.

Importing XMLU files is very similar to opening a project file. When selected, a window allowing you to browse the contents of your computer and other connected drives will appear. Once you find the XMLU file you are seeking, simply bring it in by clicking the "Open" button. If the process was successful, you will be prompted with the option to overwrite or append the contents of the file to the data currently in memory. The data tree will automatically be updated to display the latest set of data.

5.3 Importing UniSettle 4.0 Files

XMLU files created with UniSettle 4.0 may also be imported directly into UniPile 5.0. Importing these types of files is very similar to importing UniPile 4.0 Files.

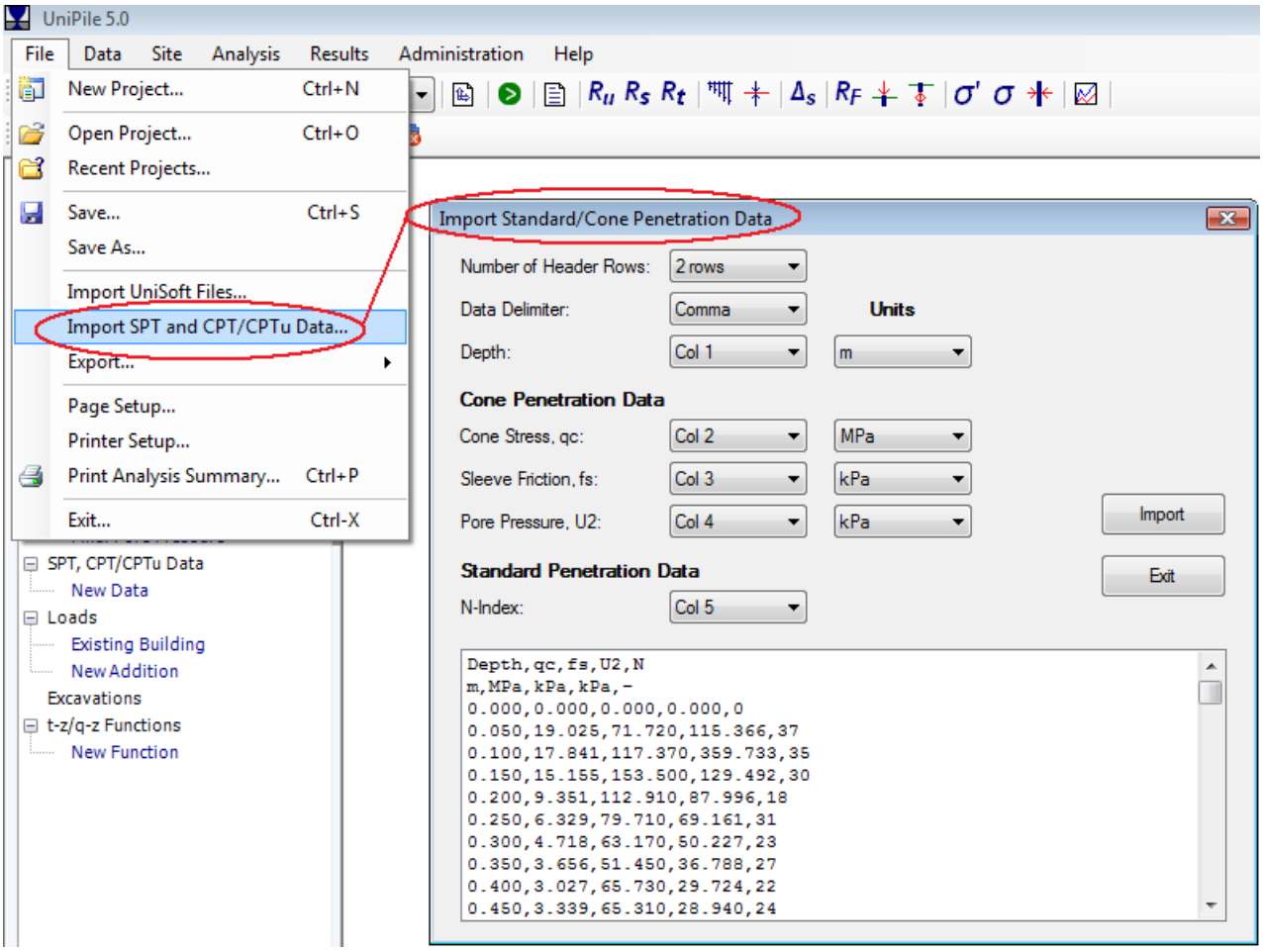
UniPile 5.0 introduces new concepts that were not part of older versions of UniPile or UniSettle. As such, the importing feature must make many decisions and revert back to internal defaults when dealing with data unique to UniPile 5.0. We strongly suggest that you review each input data before proceeding with your analysis.

Important
In UniPile 4.0, one could specify a load (or excavation) to act only at "Initial" condition. In UniPile 5.0, this condition may now be modeled by introducing a negative copy of the same load applicable at a final time period. When imported into UniPile 5.0, similar conditions require the manual addition of counteracting loads (or excavations).

5.4 Import SPT, CPT/CPTU Data

UniPile 5.0 offers the option of calculating the pile resistance using various method for using cone penetration and standard penetration test data. These data often come in ASCII text files of various format and units. This feature allows you to import these data directly into the UniPile file without having to do manual re-entry.

Note, that the CPT/CPTU records and STP records cannot be placed together in a common file. If an analysis is desired for both types of records, two separate UniPile Files will have to be created; one with the CPT/CPTU data and one with the STP data.



The import window consists of a series of standard parameters that UniPile will use to import and convert the data to an acceptable format.

Number of Header Row

Select the total number of rows representing the file header. These rows will be disregarded by UniPile to move the cursor to the start of the numerical records.

Data Delimiter

Select the type of characters delimiting the data. You may select between Spaces, Comma, or Tab. If none of these 3 options allows you to correctly import your data, you may have to open your raw data into any other compatible format and modify them accordingly.

Column and Units

For each set of data required by UniPile, specify the column and the units applicable to the data that will be imported in UniPile.

Once SPT or CPT/CPTU data have been successfully imported into UniPile, they will become part of the project data. Importing a new set of data will automatically reset the previous data.

Important:
Due to the large number of records that may have to be imported into UniPile, there is no way to edit or enter these records manually at this time. When faced with a few entries, we suggest to enter the data in an ASCII text file, then import the data as described above.

Once imported into your project, SPT, CPT, and CPTU data may be accessed from the data tree under the heading SPT, CPT/CPTU Data. Refer to Section 14.0 - SPT, CPT/CPTU Data for more details on this topic.

5.5 Export to XMLU File

UniPile 5.0 has exporting capabilities for XMLU files. Although very specific to UniPile 5.0 and UniSettle 4.0, the XMLU file format is based on the popular extensible mark-up language (XML). In short, XML is a set of rules for encoding documents into machine-readable form.

When used in conjunction with the importing features of UniPile and UniSettle, exporting of soil layers, pore pressure profiles, loads, excavations, and t-z/q-z functions, this feature allows you to quickly combine data from one project with another. It may also be used to build separate libraries of components to be imported into various projects.

Exporting XMLU files is very similar to saving a project file. When selected, you will always be presented with an environment window giving you the option to browse and save your data using the filename and folder of your choice.

5.6 Export Site Plan to Bitmap

The site plan may be exported to a high resolution colour bitmap image by accessing the "Export Site Plan" option located under the main "File" menu. Exporting the site plan is similar to saving a project file. When selected, you will be presented with an environment window giving you the option of browsing and saving your data using the filename and folder of your choice.

5.7 Export Results to Excel

The complete set of results currently in memory may be exported to an Excel (.xls) file. Exporting the results is similar to saving a project file. When selected, you will be presented with an environment window giving you the option to browse and save the results using the filename and folder of your choice. The specific set of data exported is dictated by the conditions specified in the many result drop-down boxes located in the secondary toolbar.

Tip
Because the exported data is a combination of text and numbers, Excel converts each cell using its "General" format. If you plan to perform formatting or mathematical operations on some of the data, you may have to manually convert the format from "General" to "Number". Depending on your version of Excel, there are many ways to do this; one of the simplest is to use the "Paste Special" feature of Excel as follows:

1. In an empty cell, enter the number 1, "select the cell" and, select "copy".
2. Select the range of cells to be converted.
4. From the main "Edit" menu, select "Paste Special".
5. Under "Operation", select "Multiply" and click "OK".

5.8 Export Results to Text File

As an alternative to exporting to Excel, results may be exported to a Tab delimited text file. Contrary to exporting to Excel, exporting to a text file is context sensitive, meaning that only the results currently on top (with the focus) may be exported.

5.9 Export Chart to Bitmap

The chart currently on screen may be exported to a color bitmap image for further manipulation or insertion into a report. Exporting a results chart is similar to exporting the site plan. When selected, you will be presented with an environment window that gives you the option to browse and save your data using the filename and folder of your choice.

6.0 ADMINISTRATION

The features located under the main "Administration" menu are related to the general management of the application itself. Access it to set personal preferences, to upgrade to a new release, or to activate the application after purchase.

6.1 User Preferences

Preferences are settings that control a user's account and various aspects of the user's viewing and editing environment. Preferences include the default project folder, system units, numerical format, and much more. User preferences are discussed in detail in Part II of this document.

6.2 Check for New Update

Use this option to automatically contact our Internet server and verify if a new release of UniPile is available. Upgrading is discussed in our Getting Started document.

6.3 Register UniPile

Use this option to register your copy of UniPile after installation. Registration is discussed in our Getting Started document.

6.4 Activate UniPile

Use this option to activate your copy of UniPile after installation. Activation is discussed in our Getting Started document.

6.5 Advanced

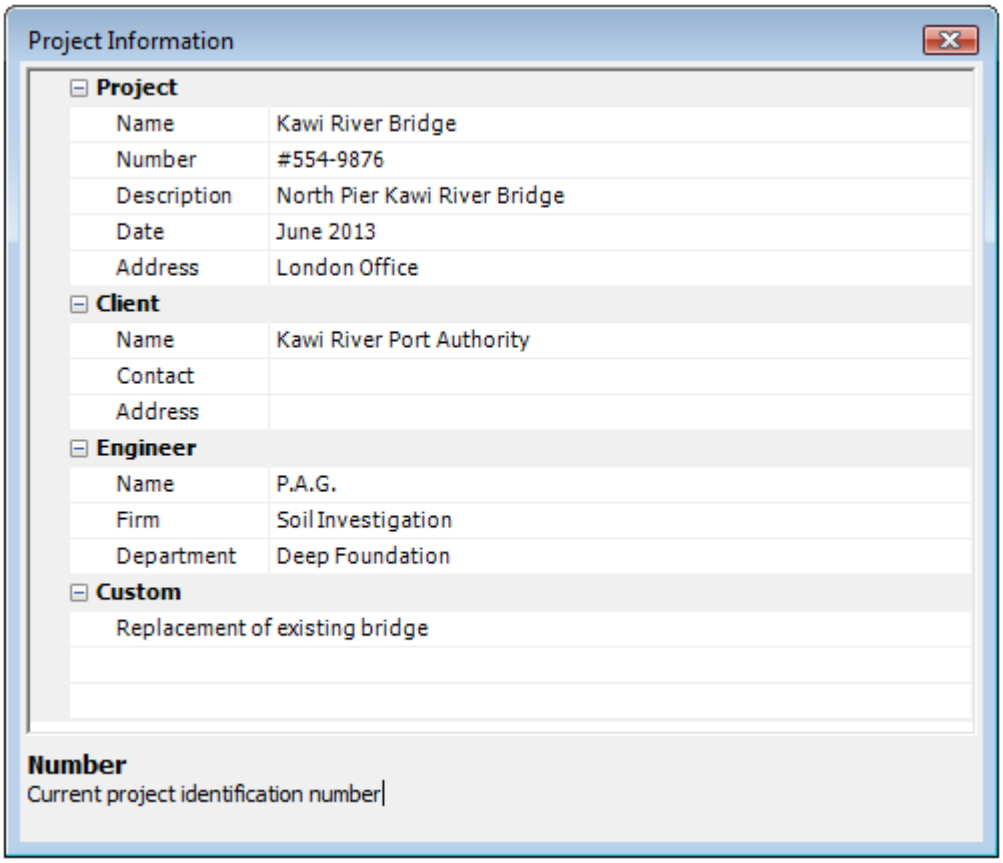
The advanced menu was incorporated to help us resolve technical issues that may occur from time to time. When reporting a problem to our technical support department, we may ask you to access one of these commands and provide us with some of the log files the software is producing at run time. We may also ask you to reset the software defaults or your activation licence.

PART II (Sections 7 through 17)

This section of the manual provides a detailed description of the variables used throughout the software. Some of these variables may not always be available or visible as many are dependent on the specified conditions or the type of version you are running.

7.0 PROJECT INFORMATION

The project information window lists the general input relating to the project under consideration. The information entered on this form has no specific effect on the end results of an analysis except for display and reporting purposes.



7.1 Project

Use this section of the form to specify general information relating to the project under consideration. The entries listed under this subject are also displayed in the "Recent Projects..." window located under the main "File" menu. The "Name" input is also displayed on the interface status bar and many of the printouts.

7.2 Client

Refers to general client information. The information specified under this topic is also used in the "Recent Projects..." window located under the main "File" menu.

7.3 Engineer

Use this section to specify general information regarding the engineer working on the analysis. The defaults used under this heading may be personalized by accessing the "User Preferences..." option located under the main "Administration" menu.

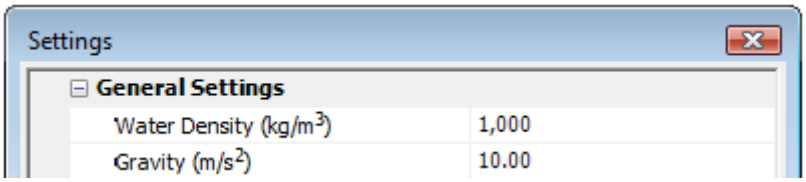
7.4 Custom

This section of the form provides 3 additional lines of input to record the information of your choice.

8.0 SETTINGS

Use this window to specify the various settings, methods, and constants used throughout the analysis. The visibility and availability of some of these entries depends on the options selected.

8.1 General Settings



Water Density
The water density used in the calculation of static pore pressure. It is used to convert pore pressure measurements from height to pressure.

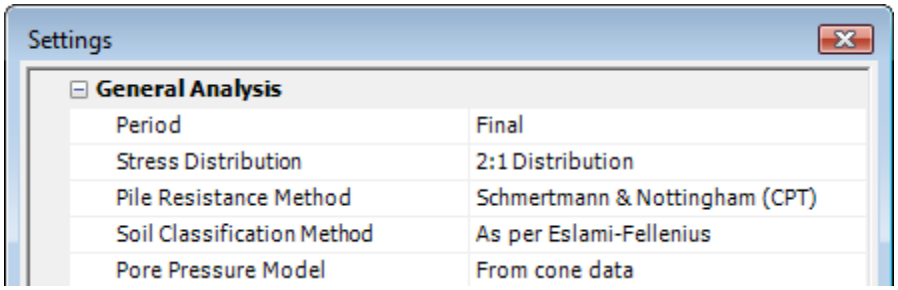
Gravity
Gravity is a constant (local gravitational field) for converting mass to weight (force). It is used throughout the application to convert kg (kilograms) to kPa (kilopascals) and pounds to pound-force. By default, the gravity constant on earth is set to 9.81 m/s^2 (32.19 ft/s^2). Gravity actually ranges from 9.77 m/s^2 in Mexico City and Singapore through 9.82 m/s^2 in the Artic. For most geotechnical engineering purposes, a value of 10.0 m/s^2 is precise enough.

The option of changing the gravity constant is for compatibility with previous versions of UniPile and to facilitate the validation of calculations performed in the SI- system.

Important
When converting from SI to Customary US units, the software ignores the gravity constant and uses commonly used conversion factors (i.e. 1 kg = 2.20 lb, 1 lb/ft^3 = 16.02 kg/m^3).

8.2 General Analysis

Use this section of the form to select the various methods of analysis (methodology) used by UniPile during the analysis.



Period
Use this entry to define the conditions under which the pile resistance is calculated. Technically the pile ultimate resistance is directly related to the effective stress in the soil. The period selected in this window does not affect the calculation of the soil settlement in the vicinity of the pile. The settlement is calculated using the change in effective stresses between the final and initial conditions.

Important
Starting with UniPile 5.0, a load (or an excavation) specified as "Initial" continues to exist into the "Final" condition ("period"). If the scope of the load (or excavation) is meant to be temporary and removed after the initial stage of construction, a second case of the same load, but now negative, must be specified at the "Final" period. This concept is compatible with UniSettle 4.0.

Stress Distribution
UniPile 5.0 performs stress distribution using Boussinesq, Westergaard, or 2:1 Distribution. Use this entry to select the method to be used in the analysis. The stress distribution method applies to loads, excavations, and pile group.

Pile Resistance Method
Select the method used in the calculation of the pile ultimate resistance. Available options are: Static (effective stress and total stress, i.e., ß- and α-methods), CPTU (Eslami and Fellenius), CPT (Schmertmann and Nottingham, deRuiter and Beringen–Dutch, and Bustamente–LCPC), and SPT N-indices (Meyerhof, Decourt, and O'Neill-Reese). For requirements, see the "Red Book" (referenced Section 1.1.4).

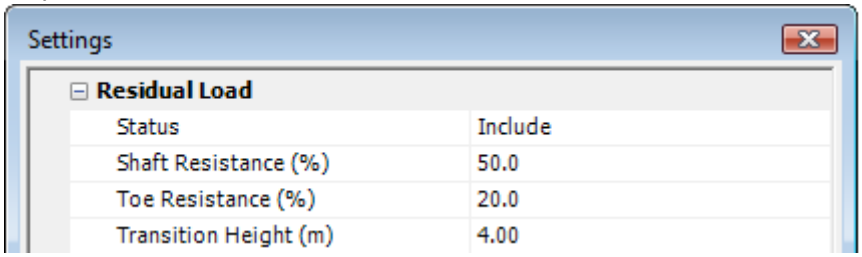
The Static method refers to both the Beta and Alpha methods. They can be combined or used separately.
The analysis can be performed for either the initial or final period.

Soil Classification Method
The type of soil (e.g., Clay or Sand) is a required input for some of the pile resistance methods. When necessary, the soil classification may be obtained from the Eslami-Fellenius method or dictated by the user in each of the soil layers.

Pore Pressure Model
The pore pressure model is a required input when the Eslami-Fellenius soil classification model is selected. To be correct, the Eslami-Fellenius soil classification method uses the cone stress corrected for pore pressure acting against the shoulder. This option allows the Eslami-Fellenius soil classification to use either the pore pressure obtained from the CPTU imported data or use the pore pressure model specified in the pore pressure input.

8.3 Residual Load

Use this section to specify the parameters used in the distribution of the residual load in the pile shaft and pile toe. The residual load affects the results of a static loading test. See also comments in Section 16.1, Page 67 and in Examples Manual, Example 2.



Status
Use this entry to include or disregard the effect of residual load on the pile. If included, the residual load will be included in the static loading tests (head-down and O-Cell) simulation.

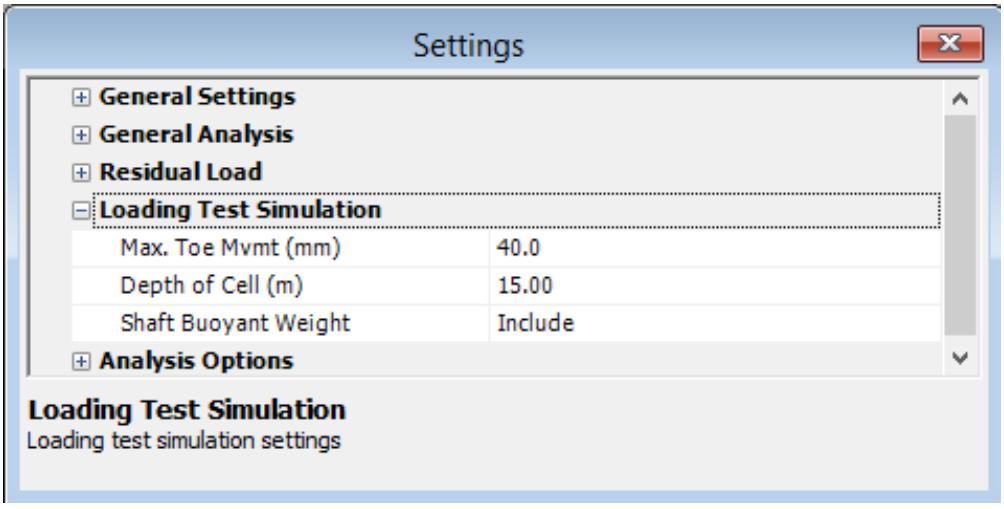
Shaft Resistance
Enter the percentage of shaft resistance (% of r_s) to be used in the calculation of the total residual load. This value represents the percentage of mobilization of the shaft unit resistance.

Toe Resistance
Enter the percentage of toe resistance (% of r_t) to be used in the calculation of the total residual load. This value represents the percentage of mobilization of the ultimate toe resistance.

Transition Height
Enter the estimated height of the transition zone controlling the transition between negative and positive direction of shear forces at the neutral-plane. The transition represents the portion where the unit shaft resistance transfers from negative to positive direction. It has the effect of reducing the maximum value of residual load in the pile. The mechanism generating residual load is essentially the same as that generating drag force.. However, the height is not necessarily the same as that input under the Pile Data (Section 10.0) because the relative movement between the pile and the soil building up residual load is usually smaller than the settlement that results in building up a drag force in the pile. The height input is therefore usually longer.

8.4 Loading Test Simulation

Use this section to specify the parameters affecting the static loading test simulation. The static loading test simulation (head-down andvidirectional-cell) combines the calculated pile resistance with the pile/soil behavior movement curve (t-z and q-z functions) to simulate the results of a static loading test.



Max. Toe Mvmt
Use this entry to specify the maximum toe movement used in the static loading test simulation (head-down and O-cell).

Depth Bidirectional Cell
Use this entry to specify the depth of the Bidirectional Cell.

Shaft Buoyant Weight
In order to move the pile above the cell level upward, the bidirectional cell must overcome the pile weight in addition to the soil resistance. Moreover, an actual test includes the effect of the pore pressure acting at the cell level after the bond in the pile is broken (the first effect of engaging the cell), which pore pressure then introduces a water force that acts both upward and downward. Upward, the water force reduces the effect of the pile weight to that of the buoyant value. Downward, the water force adds to the cell load in engaging the downward response of the pile. (So does the pile weight, but as this is the same for a head-down test, this effect is conventionally disregarded).

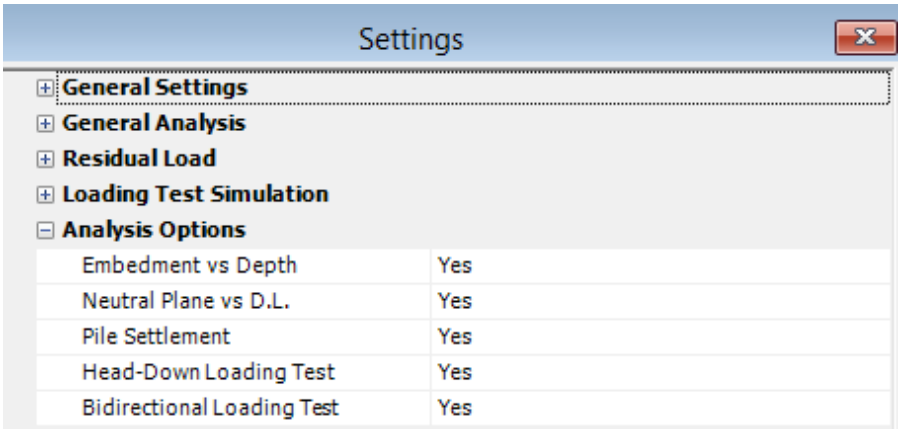
The User decides whether to "include" or "disregard" the effect of the pore pressures on the pile ("Shaft Buoyant Weight") for the bidirectional test simulation. When "included", UniPile uses the pore pressure at the cell level to calculate the buoyant weight of the shaft portion located above the cell level and add this to the calculated shaft resistance to generate the simulated upward load-movement curve. Similarly, the water force is added to the cell load in engaging the downward response (the shaft and toe resistances below the cell level).

When "disregarded", UniPile makes no adjustment for the water force for either upward or downward simulation of the load movement curves of the bidirectional test.

Because, the cell load is determined from the pressure at the pump placed at the ground surface, the cell pressure is actually larger than that measured in the pump (the hydraulic fluid is water). The difference corresponds to the head of water between the cell and the pump. Moreover, the pore pressure in the soil at the cell level can only act on the area not covered by the cell(s). Therefore, on the approximation that the head of water between the cell and the pump is equal to the head of water corresponding to the pore pressure at the cell level, the water force at the cell level corresponds to the pore pressure times the full pile cross section.

8.5 Analysis Options

This section of the settings allows the user to disable portions of the analysis to speed up the calculations and to reduce the output produced by the software.



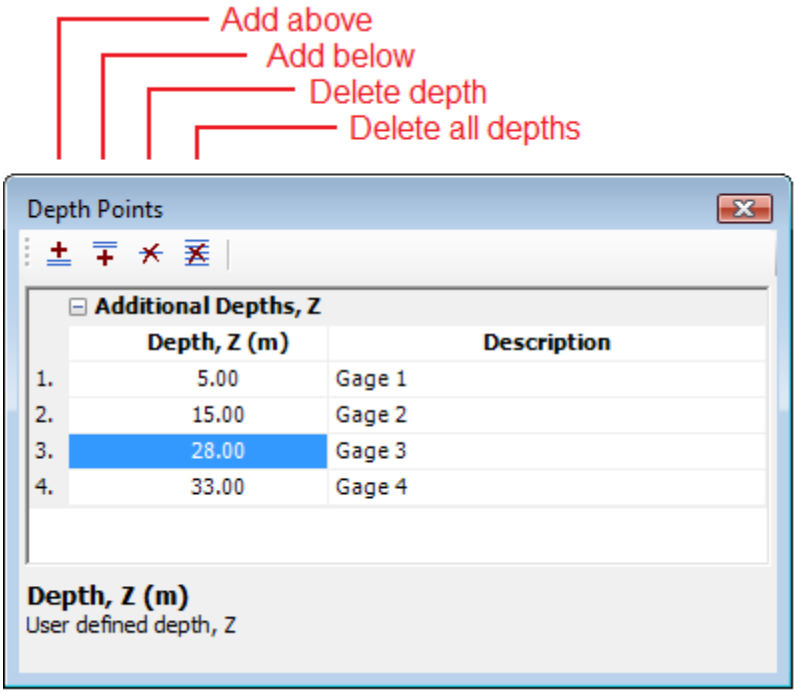
Depending on the type of version installed in your computer, some of these features may not be available.

9. DEPTH POINTS

By default, UniPile calculates and displays the results at depths defined in each soil layer (via the "Z Steps" input). Use this feature to specify additional depths of interest, e.g., when back-calculating the results of an instrumented static loading tests—be it a head-down or bidirectional test.

9.1 Additional Depths

Additional depths are defined by entering a depth value. Depth points are added or deleted using the action buttons located at the top of the window.



Important
Action buttons are only enabled when the focus is on a specific depth.

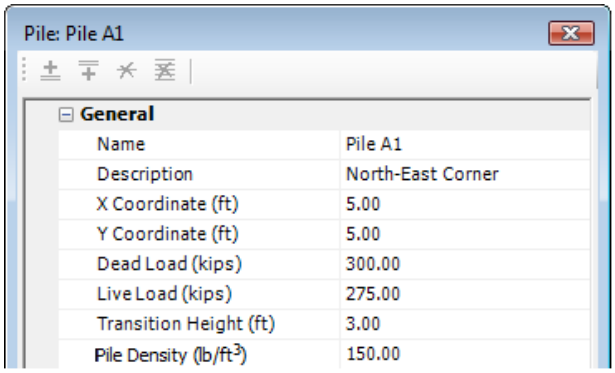
10. PILE DATA

The pile data window includes some general entries, various resistance parameters, and the pile geometry. The visibility and availability of some of these entries depends on the options selected.

Important
The purpose of this section is not to explain each parameter in detail and how they apply to the calculation of the pile ultimate resistance. For more information we recommend that you refer to the original paper describing each method and/or consult Basics of Foundation Design by Bengt H. Fellenius, Dr. Tech., P.Eng., available online at [*http://www.UniSoftltd.com/Uploaded/downloads/RedBook.pdf*](http://www.UniSoftltd.com/Uploaded/downloads/RedBook.pdf)

10.1 General

Use this section of the pile data input window to specify the more general input parameters.



Name
Use this entry to specify a name for the pile under consideration. We suggest keeping this name short and descriptive as it is used in the data tree and the many outputs.

Description
Enter a description of your choice. This entry has no effect on the rest of the results and is provided for information only.

X,Y Coordinates
Specify the Cartesian (X,Y) coordinates of the pile under consideration. These coordinates are important as they are used as the target coordinates to distribute and calculate the effective stresses acting on the pile.

Dead Load
Use this entry to specify the amount of dead load (also called "sustained load")on the pile. The dead load is used to obtain the location of the neutral plane and, in combination with the drag force, estimating the maximum axial force in the pile.

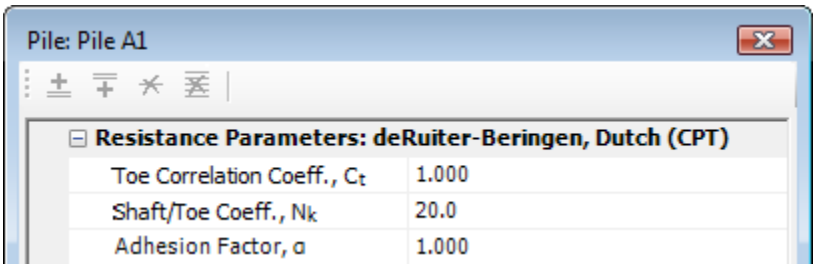
Live Load
Use this input to specify the amount of live load acting on the pile. The live load is used to calculate the factor of safety based on the pile ultimate resistance. It has no bearing on the pile compression or settlement. Notice, so-called "sustained live loads" may act as dead load in determining the location of the neutral plane and the maximum axial force in the pile

Transition Height
Enter the estimated transition height above the neutral-plane. The transition represents the portion where the unit shaft resistance switches from negative to positive directions of shear. The transition height is usually not the same as that specified under the Residual Load feature (Section 8.3). Its value affects—reduces—the amount of drag force acting on the pile. The height of the transition zone is a function of the soil settlement at the depth of the neutral plane. Approximately, the height can be chosen to twice the distance between neutral plane and up where the relative soil settlement is 3 to 5 mm larger than the value at the neutral plane, or, similarly, twice the distance down to where the settlement is that same amount smaller than the value at the neutral plane. Thus, where the soil settlement around the pile is small the height is large and, conversely, where the soil settlement is large, the height is small.

Pile Density
Use this entry to define the density of the material used in the construction of the pile shaft. The density is used to calculate the pile weight when considering the simulate of the bidirectional test.

10.2 Resistance Parameters

Use this section of the input window to specify the pile resistance parameters for analysis using CPT/CPTU and SPT records; different methods requiring different input. The visibility and availability of some of these entries depends on the pile resistance method selected under the general analysis settings (Section 8.0). For specific requirements, see the "Red Book" (referenced Section 1.1.4).



Pile Type
Select one of the pre-defined pile types: Steel, Concrete, or Wood. The pile type is a required input when selecting the Schmertmann-Nottingham or the Bustamente (LCPC) methods.

Installation Method
Select one of the pre-defined installation methods: Driven, Bored, or Screwed. The pile installation method is a required input when selecting the Bustamente (LCPC) or the Meyerhof (SPT) methods.

Toe Influence Zone
Select one of the pre-defined toe influence zones: Weak/Dense or Dense/Weak. The toe influence zone is a required input when selecting the Eslami-Fellenius (CPTU) method.

Toe Correlation Coeff., C_t
Use this entry to specify the toe correlation coefficient used in the calculation of the toe resistance. This toe correlation coefficient is a required input when selecting the Eslami-Fellenius (CPTU), Schmertmann-Nottingham, or the deRuiter-Beringen (Dutch) method in sand.

Note:
The toe resistance of a pile in sand according to the deRuiter-Beringen (Dutch) method is the same as the Schmertmann-Nottingham method.

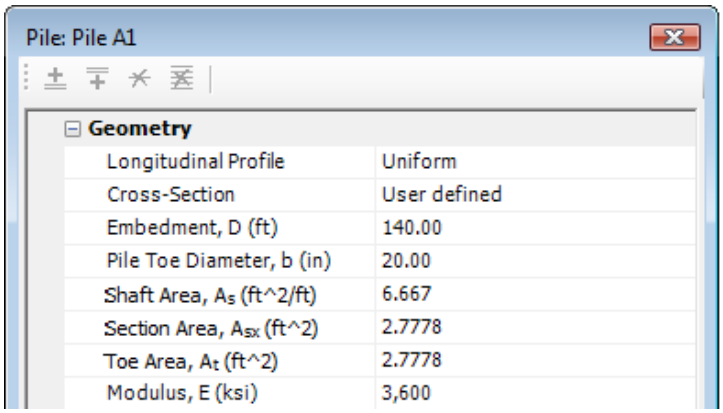
Shaft/Toe Coeff., N_k
Use this input to specify the shaft/toe correlation coefficient used in the calculation of the shaft and toe resistance of piles in clay according to the deRuiter-Beringen (Dutch) method.

Adhesion Factor, α
Use this entry to specify the shaft adhesion factor according to the deRuiter-Beringen (Dutch) method.

Energy Correction Coeff., C_e
Energy correction coefficient applicable to the Meyerhof (SPT) method.

10.3 Geometry

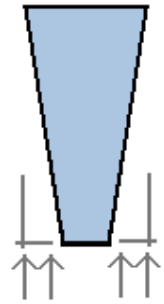
This section of the pile data window describes the general geometry of the pile under consideration. The visibility and availability of some of these entries depends on the selected profile and shape of the pile.



After completing the analysis, the interpolated pile geometry may be obtained by accessing "Pile Profile." located under the main "Results" menu.

Longitudinal Profile
Use this entry to define the longitudinal profile of the pile. Available options are Uniform or User Defined. Uniform means that the pile cross-section remains constant throughout the entire length of the pile. Selecting User Defined allows you to define varying cross-sections at various depths along the pile. This feature allows you to precisely model the shape of wood or expended base piles. How to define a pile profile varying with depth is discussed in Section 10.4 - User Defined Longitudinal Profile.

Taper Effect
This option is available when a user-defined pile profile is selected. Including the taper effect in the analysis means that the vertical component of the soil resistance will be included in the total shaft resistance of the pile. When doing so, UniPile uses the specified toe resistance parameters at that specific location combined with the shaft projection area to calculate that portion of the shaft resistance.



In practice, a pile ultimate resistance to uplift may be assumed to be equivalent to the pile ultimate shaft resistance. Please note that the taper effect calculated by UniPile applies only to the downward resistance and should not be considered in the pile capability when resisting uplift.

Cross-Section
Use this entry to select the pile cross-sectional shape. Pre-defined shapes include Round, Square, Hexagonal, and Octagonal. Piles of all shapes and forms may be defined by selecting "User defined". When combined with a user defined longitudinal profile, piles of all shapes, forms, and size may be defined. This includes H-Piles, barrettes, and open pipe piles.

Embedment, D
Use this entry to specify the ultimate pile embedment used during the analysis. When a "User-defined" longitudinal profile is selected, the pile embedment is taken from the user defined profile geometry. How to define a pile profile varying with depth is discussed in Section 10.4 - User Defined Longitudinal Profile.

Pile Toe Diameter, b
Input of the specifics of the pile toe diameter is required by the Eslami-Fellenius (CPTU), Schmertmann-Nottingham, deRuiter-Beringen (Dutch), and the Bustamente (LCPC) methods to calculate the toe influence zone. It is necessary for a pile with a user-defined cross-section. For other pre-defined shapes, the pile toe diameter is assumed to be equal to the pile diameter, b.

Diameter, b
When selecting one of the pre-defined shapes, revising the pile diameter automatically re-calculates the geometrical properties of the pile. For polygonal shapes such as square or octagonal, the pile diameter is measured from face-to-face (i.e. a circle fitting inside the shape).

Shaft Area, A_s
Use this entry to define (or overwrite) the pile shaft surface area (i.e. area per unit length). Input of the unit shaft area is necessary when a user defined shape is specified. Alternatively, the unit shaft areas are automatically calculated from the shape of the pile and the specified pile diameter. The shaft area, A_s, is used in the calculation of the shaft resistance.

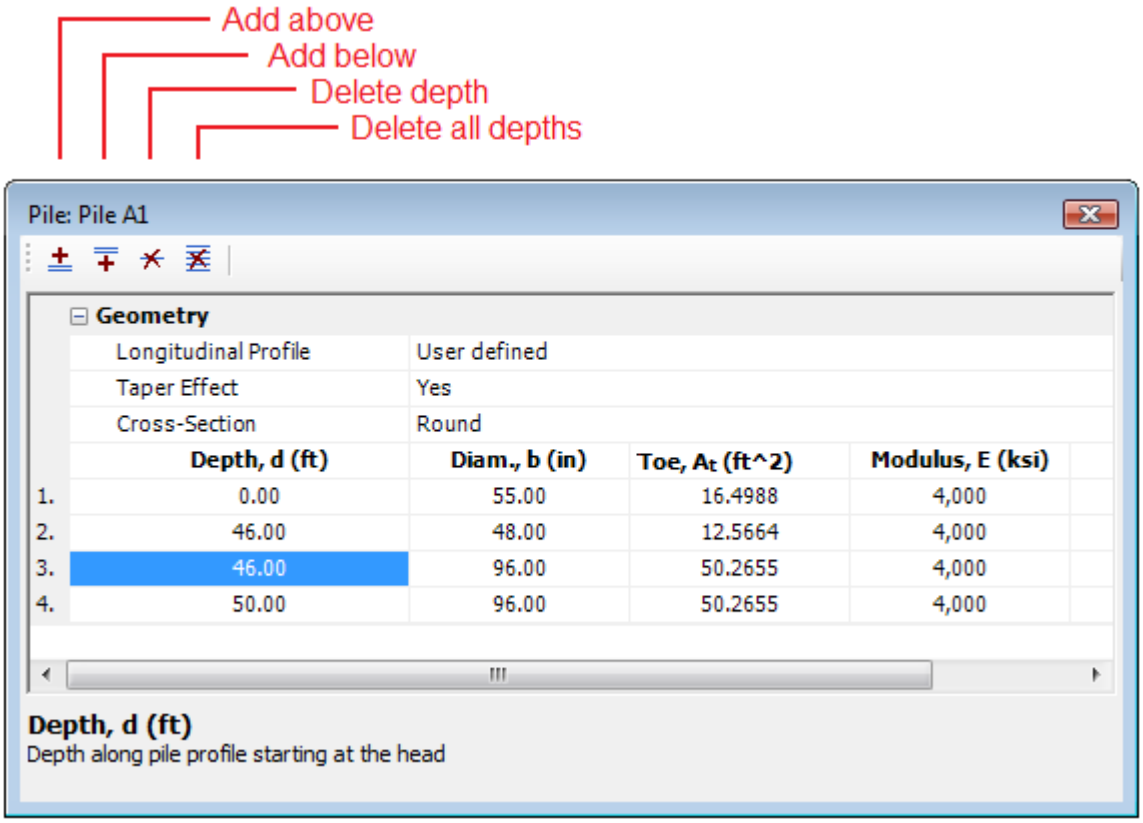
Section Area, A_{sx}
Use this entry to define the pile cross-sectional area. Input of the unit shaft area is required when a user defined shape is specified. Alternatively the unit shaft areas are automatically calculated from the shape of the pile and the specified pile diameter. In UniPile the pile section area is combined with the pile modulus of elasticity to calculate the pile compression.

Toe Area, A_t
Use this input to define the exact pile toe area used in the calculation of the pile ultimate toe resistance. Having the capacity to specify the pile toe area independently from the pile section area allows the analysis of open toe piles and expanded-base piles.

Modulus, E
This entry defines the pile shaft according to the Young's modulus of elasticity. In UniPile, the pile modulus of elasticity is combined with the pile cross-sectional area, A_{SX}, to calculate the pile compression and in the simulation of the static loading test—head-down and bidirectional.

10.4 User Defined Longitudinal Profile

When selecting a "User defined" longitudinal profile, the pile data window automatically shows the pile's geometrical properties as a function of depth.



A user defined pile profile is built by adding or inserting new rows of input to the pile profile. For each row added, new input of depth, diameter, shaft areas, and modulus is required.

Important

Action buttons are only enabled when the focus is on a specific series. The specific properties that must be entered depend on the cross-section selected. When one of the pre-defined cross-sections is selected, the user is required to specify the pile diameter at each specified depth. When "User defined" cross-section is selected, individual areas must be entered.

Important

The shape of the pile affects how UniPile interpolates the pile geometry during the analysis. When one of the pre-defined shapes is selected, UniPile interpolates the pile profile based on the specified pile diameter. If the "User defined" shape is selected, interpolation is based on the specified area.

11. PILE GROUP DATA

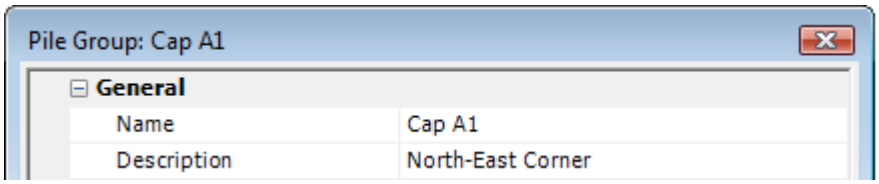
Piles are rarely installed alone (as single piles). They are most often located in groups and are interconnected via a pile cap.

In UniPile, the pile group data are used to calculate the settlement of the soil in the vicinity of the pile under consideration. Others piles located in the vicinity will in theory impose additional stresses on the pile under consideration and this could affect the ultimate resistance. Despite this, in UniPile, the load imposed by the pile group is used only in the calculation of the settlement and is not included in the pile resistance analysis. However, the effect of close-by pile groups may be included in the pile resistance analysis by adding their effect as additional loads.

Important
The purpose of this section is not to explain each parameter in details and how they apply to the calculation of the pile's ultimate resistance or the settlement calculation. For more information, we recommend that you refer to the "Red Book": Basics of Foundation Design by Bengt H. Fellenius, Dr. Tech., P.Eng., available online at http://www.UniSoftltd.com/Uploaded/downloads/RedBook.pdf.

11.1 General

Use this section of the pile group window to specify the more general input parameters.

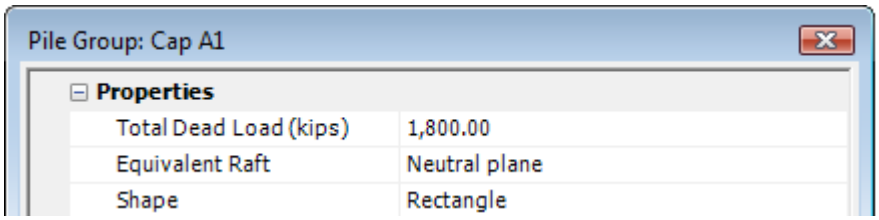


Name
Use to specify a name for the pile group under consideration. We suggest keeping this name short as it is used in the data tree and some of the results windows.

Description
Use this to enter the description of your choice. This entry has no effect on the rest of the results and is provided for information only.

11.2 Properties

Use this section of the pile group window to specify more specific properties applicable to the pile group under consideration.



Total Dead Load
The total dead load is the permanent (or sustained) load applied to the entire pile group. It should be the sum of the dead load for all the piles in the group. This total dead load is only used in the calculation of the settlement of the soil surrounding the pile under consideration.

Equivalent Raft
Use this option to define the location of the equivalent raft used in the calculation of the soil settlement around the pile under consideration. Available choices are "Pile toe", "Neutral plane", and "User defined". If placed anywhere else than at the pile toe, the width and breath of the raft must consider the distribution between the position and the pile toe. The Red Book suggests the load spreading to be 5(V): 1(H).

Depth of Raft
Use this entry to impose a specific depth to the equivalent raft. This input is only available when "User defined" equivalent raft is selected.

Shape
Use this entry to select the geometric shape of the pile group under consideration. Available shapes are “Rectangle” or “Polygon”.

11.3 Geometry

Use this section of the pile group window to specify the exact geometry of the pile group under consideration. The entries available under this topic depend on the selected shape of the pile group under consideration. The following image shows the available entries for a rectangular shape pile group.

Breadth, B
Defines the breadth (or width) of a rectangular shape pile group. It refers to the dimension measured along the East-West direction (X-Axis).

Length, L
Defines the length of a rectangular shape pile group. It refers to the dimension measured along the North-South direction (Y-Axis).

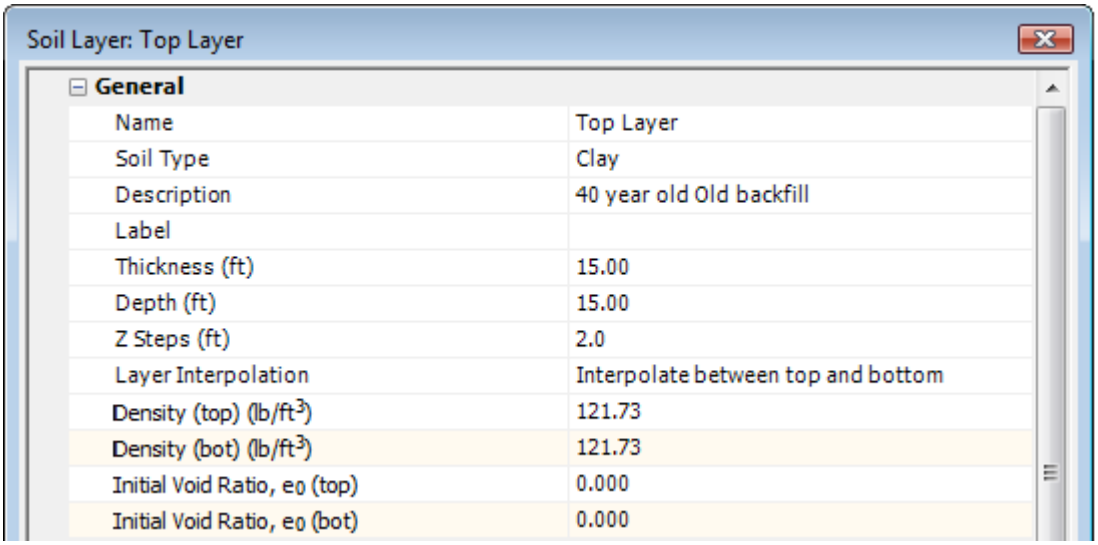
X and Y Coordinates
These coordinates define the exact location and shape of a polygon type pile group. Coordinates must be specified in a clockwise fashion.

12. SOIL LAYERS

Use this input form to specify the various soil properties and parameters used throughout the analysis. The values specified in this window apply to the soil layer under consideration (i.e. selected from the data tree). The visibility and availability of some of these entries vary depending on the many available options.

Important
The purpose of this section is not to explain each parameter in detail and how they apply to the calculation of the pile's ultimate resistance or settlement. For more information, we recommend that you refer to the Basics of Foundation Design by Bengt H. Fellenius, Dr. Tech., P.Eng.. available online at *http://www.UniSoftltd.com/Uploaded/downloads/RedBook.pdf*

12.1 General



Name
Use to specify a name for the soil layer under consideration. We suggest keeping this name short as it is used in the data tree and the results windows and combo boxes.

Soil Type
Use this entry to define the type of soil used in the calculation of the pile resistance. The type of soil (Clay or Sand) must be specified when the pile resistance is calculated using the Schmertmann-Nottingham, deRuiter-Beringen (Dutch), the Bustamente (LCPC) or Decourt methods. This input is disabled in the event that the Eslami-Fellenius soil classification is specified in the general settings.

Description
Use this to enter the description of your choice. This entry has no effect on the rest of the results and is provided for information only.

Label
Use this entry to override the label that is presented at the top of each layer in the results table. If left blank, the layer number within the profile and the name previously assigned is used.

Thickness
Defines the thickness of the layer under consideration. Setting this value to 0 automatically disables the layer and disregards it during calculations. Changing the thickness of a layer automatically revises the depth of the layer under consideration and other layers located below.

Depth
Use this entry to specify the depth at the bottom of the soil layer under consideration (as an alternative to the thickness). Changing the depth automatically updates the thickness of the layer under consideration.

Z Steps
Use this value to define the integration steps along the thickness of the soil layer under consideration. When set to "0", the integration steps are equal to the thickness of the layer. Using a small value, proportionally increases the time necessary to perform the calculations.

Important
To improve the performance and precision of the results, it is important to use engineering judgment when selecting integration steps. For obvious reasons, input of smaller integration steps around the neutral plane is more useful than smaller integration steps deep in other layers.

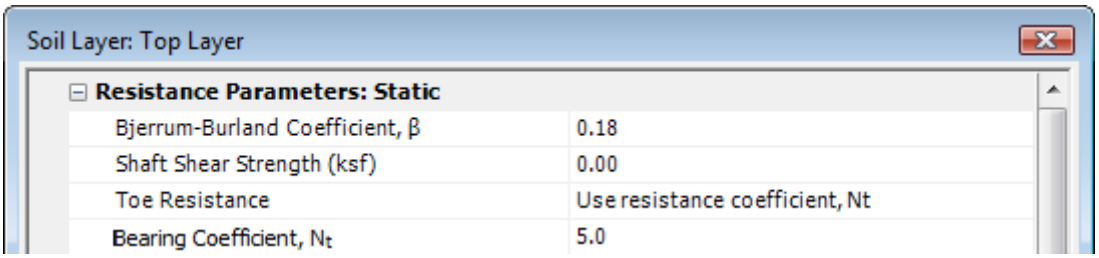
Layer Interpolation
By default, the soil properties and parameters are usually considered to be an average over the entire thickness of the layer. When selecting "Interpolate between top and bottom", the user is then required to specify the properties at the top and the bottom of the layer under consideration. When performing the calculations, the properties specific to a particular depth are interpolated accordingly.

Density
Defines the total (bulk) soil density for the layer under consideration. The soil density is used in the calculation of the total stresses.

Initial Void Ratio, e_0
Use this entry to specify the initial void ratio of the layer under consideration. The initial void ratio is used in the calculation of the soil consolidation when the conventional method, $C_c e_0$, is selected.

12.2 Resistance Parameters

The entries specific to this topic are used in the calculation of the pile shaft and toe resistance. The availability of some of the entries located under this topic varies depending on the pile resistance method selected in the general settings.



Bjerrum-Burland Coefficient, β
Specifies the Bjerrum-Burland beta-coefficient used in the calculation of the shaft resistance when using the Static (Beta) method–the ß-method.

Shaft Shear Strength
Specifies the shaft shear strength or effective cohesion that can be applied directly to the pile shaft resistance independently of the effective stress–the alpha-method.

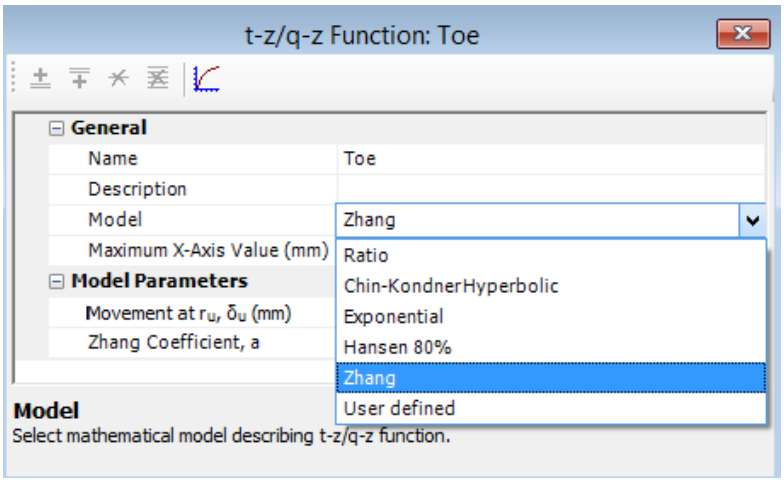
Toe Resistance
Selects the method used to calculate the toe resistance when the Static method is selected. Available options are a bearing resistance coefficient, N_t, or a fixed unit toe resistance, r_t.

Bearing Coefficient, N_t
Use this entry to specify a bearing resistance coefficient, N_t. This bearing coefficient is later multiplied by the effective stress and the toe area to obtain the ultimate toe resistance.

Unit Toe Resistance, r_t
Use this entry to specify the unit toe resistance defined as the limit toe resistance for calculating the pile capacity. The unit toe resistance is multiplied by the toe area to obtain the ultimate toe resistance.

12.3 Resistance vs. Movement

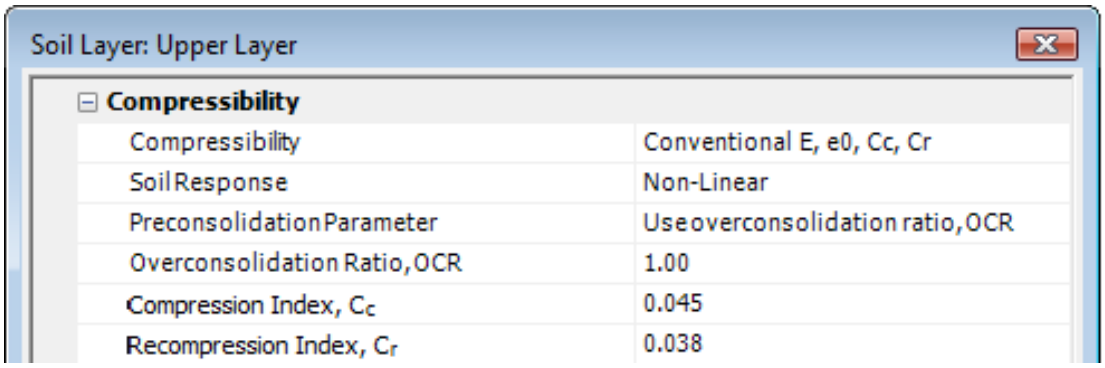
Use this section to select specific resistance vs. movement relationships for the shaft and the toe. Resistance vs. movement (t-z and q-z) functions are used in the simulation of the static head-down and bidirectional cell static loading tests.



The content of the lists (both Shaft t-z and Toe q-z) originates from the list of t-z/q-z functions defined later in the input. Please refer to Section 16.0 - t-z/q-z Functions for details on how to build the t-z and q-z functions that will be displayed in the list of available functions.

12.4 Compressibility

The entries located under this heading refer to the layer compressibility properties and parameters. Some of the entries described in this section may or may not be visible depending on the options selected.



Important

UniPile 5.0 calculates the long-term consolidation settlement of the soil in the vicinity of the pile under consideration. Immediate and secondary consolidation may be obtained by exporting the data to UniSettle 4.0 and perform the settlement calculations there.

Compressibility

Use this entry to select the preferred settlement calculation method. The available options are the Janbu modulus method or the conventional E, e_0, C_c, and C_r methods. The modulus number, m, is equal to 2.3(1+eo)/Cc. Input of the so-determined modulus number will make input of the void ratio superfluous.

Stress Exponent, j

Refers to the Janbu stress exponent applicable to the soil layer under consideration. This input is available only when the Janbu modulus method was selected previously.

Soil Response

Specifies the type of soil response (linear or non-linear). Only available when the conventional method was selected previously.

Preconsolidation Parameter

Identifies how preconsolidation is specified and calculated. Preconsolidation may be defined using the overconsolidation ratio, OCR, or the preconsolidation margin, Δσ'.

Overconsolidation Ratio, OCR

Use this entry to specify preconsolidation using an overconsolidation ratio. Setting this value to 1.0 is equivalent to disabling preconsolidation. This input is only available when the preconsolidation using the overconsolidation ratio, OCR, is selected.

Important

The overconsolidation ratio specified in this section is considered only for the calculation of the consolidation settlement and has no bearing on the calculation of the pile capacity. When the pile resistance is calculated using the Schmertmann & Nottingham (CPT) or the deRuiter & Beringen - Dutch (CPT) method, the effect of the overconsolidation on the pile resistance is considered through the toe correlation coefficient and/or the adhesion factor.

Preconsolidation Margin, Δσ'
Use this entry to specify preconsolidation using a preconsolidation margin. Setting this value to 0 is equivalent to disabling preconsolidation. This input is only available when the preconsolidation using the preconsolidation margin, Δσ', is selected.

Important
The overconsolidation ratio specified in this section is considered only for the calculation of the consolidation settlement and has no bearing on the calculation of the pile capacity. When the pile resistance is calculated using the Schmertmann & Nottingham (CPT) or the deRuiter & Beringen - Dutch (CPT) method, the effect of the overconsolidation on the pile resistance is considered through the toe correlation coefficient and/or the adhesion factor.

Virgin Modulus Number, m
Defines the Janbu virgin modulus number for the layer under consideration. Setting this value to 0 automatically disregards primary consolidation. This input is only available when the Janbu modulus method was selected previously.

Recompression Modulus Number, m_r
Defines the Janbu recompression virgin modulus number for the layer under consideration. This input is only available when the Janbu modulus method was selected previously.

Compression Index, C_c
Defines the compression index for the layer under consideration. Setting this value to 0 automatically disregards consolidation. This input is only available when the conventional method with a non-linear soil response was selected previously.

Recompression Index, C_r
Defines the recompression index for the layer under consideration. This input is only available when the conventional method with a non-linear soil response was selected previously.

Compression Modulus, E_c
Defines the compression elastic modulus for the layer under consideration. Setting this value to 0 automatically disregards consolidation. This input is only available when the conventional method with a linear soil response was selected previously.

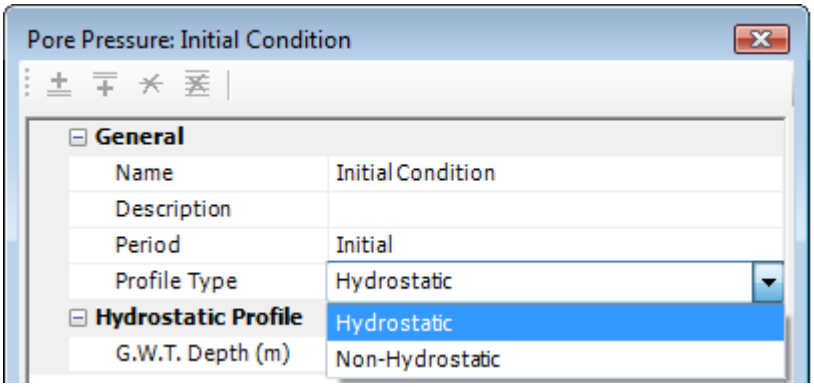
Recompression Modulus, E_r
Defines the recompression elastic modulus for the layer under consideration. This input is only available when the conventional method with a linear soil response was selected previously.

13. PORE PRESSURE

Use this input window to specify the pore pressure profiles used in the analysis. Pore pressure at initial and final conditions may be specified.

13.1 General

The entries located under this heading refer to the pore pressure profile in general.



Important
In UniPile, the pore pressure is used in the calculation of the effective stresses and to obtain the Eslami-Fellenius soil classification if specified as such in the general settings.

Name
Use this entry to specify a name for the pore pressure profile under consideration. We suggest keeping this name short as it is used in the data tree and the various results windows and combo boxes.

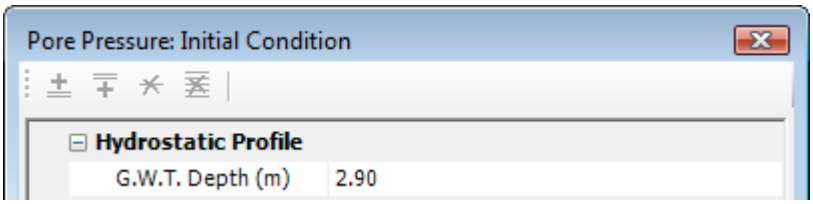
Description
Use this entry to enter the description of your choice. This entry has no effect on the remainder of the results and is provided for information only.

Period
Represents the time at which the pore pressure profile under consideration applies. In UniPile, pore pressure is set at initial and final condition. The time period in UniPile (i.e. "Initial" or "Final") cannot be edited. This entry is displayed for compatibility with UniSettle 4.0 where, however, multiple time periods may be defined.

Profile Type
Use this entry to specify the type of pore profile. Options are Hydrostatic and Non-Hydrostatic. The type of pore profile selected dictates the availability of other entries.

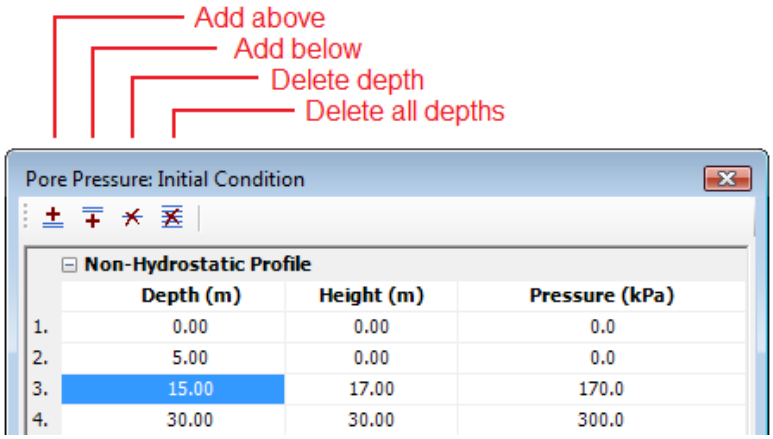
13.2 Hydrostatic Profile

The entries located under this heading apply (or entry as singular and then use applies) only when hydrostatic conditions are specified.



G.W.T. Depth
Depth of ground water table under hydrostatic conditions. The depth is measured from the ground surface at initial condition (i.e., upper boundary of the first specified soil layer). A negative value represents a marine-type condition with the top of the first soil layer representing the bottom of the lake or ocean.

13.3 Non-Hydrostatic Profile
The entries located under this heading are only applicable when non-hydrostatic conditions are specified.



Non-hydrostatic pore pressures are defined by a series of depths and equivalent heights of water (or pressure). Series may be added or deleted using the action buttons located at the top of the pore pressure window.

Important
Action buttons are only enabled when the focus is on a specific series.

Depth
Depth at which the specific pore pressure applies. To model a marine effect, specify a negative height of water (or pressure) at a depth of 0.

Height
The applicable pore pressure at the specified depth expressed in height of water. The pressure is directly related to the height of water via the water density specified in the Settings window. Changing the water density automatically updates the pore water pressure.

Pressure
Pore pressure expressed in units of stress. The height of water is directly related to the pressure via the water density specified in the Settings window. Changing one automatically updates the other. Changing the water density from the general settings updates the pressure accordingly.

14. SPT, CPT/CPTU DATA

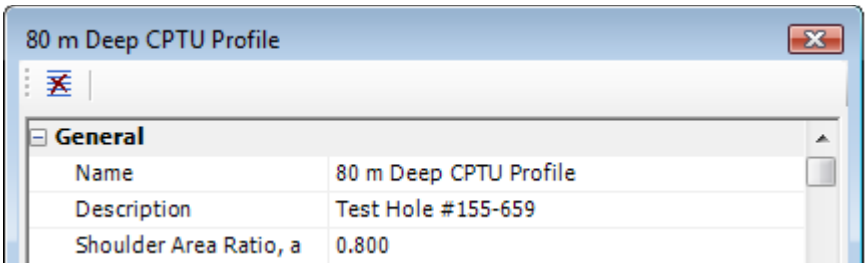
SPT, CPT, and CPTU data are required to obtain the pile resistance using other methods such as the Eslami & Fellenius (CPTU), Schmertmann & Nottingham (CPT), deRuiter & Beringen - Dutch (CPT), Bustamente - LCPC (CPT), and the Meyerhof (SPT) methods. These data are imported into UniPile via the "Import SPT, CPT/CPTU Data..." command located under the main File menu. Refer to Section 5.0 - Importing and Exporting for details on how to import data into UniPile 5.0.

Due to the large number of records that may have to be imported into UniPile, there is no way to edit or enter these records manually at this time. When dealing with a few entries, we suggest placing the data in an ASCII text file, then, importing the data as described in Section 5.4 - Import SPT, CPT/CPTU Data.

Important
Once imported, data may be reset using the reset button located at the top of the window.

14.1 General

The entries located under this heading refer to the data under consideration.



Name
Use this entry to specify a name for the data under consideration. We suggest keeping this name short as it is used in the data tree and the various results windows and combo boxes.

Description
Use this to enter the description of your choice. This entry has no effect on the remainder of the results and is provided for information only.

Shoulder Area Ratio, a
This entry represents the ratio between the shoulder area (cone base) unaffected by the pore water pressure to total shoulder area. It is used in the calculation of the effective cone pressure, q_E, when the pile resistance is calculated using the Eslami-Fellenius method.

14.2 Standard/Cone Penetration Data

This section of the window displays the data as imported. They are automatically converted to match the selected design units.

Reset Data

80 m Deep CPTU Profile

Standard/Cone Penetration Data

	Depth, d (m)	qc (kPa)	fs (kPa)	U2 (kPa)	N-Index (Blows/ft)
1.	0.000	0.000	0.000	0.000	0.0
2.	0.050	19,025.000	71.720	115.366	37.0
3.	0.100	17,841.000	117.370	359.733	35.0
4.	0.150	15,155.000	153.500	129.492	30.0
5.	0.200	9,351.000	112.910	87.996	18.0
6.	0.250	6,329.000	79.710	69.161	31.0
7.	0.300	4,718.000	63.170	50.227	23.0
8.	0.350	3,656.000	51.450	36.788	27.0
9.	0.400	3,027.000	65.730	29.724	22.0

In addition to the depth for each record, the data imported in UniPile may include the cone pressure, q_c, the sleeve friction, f_s, the measure pore pressure, and the SPT N-Index.

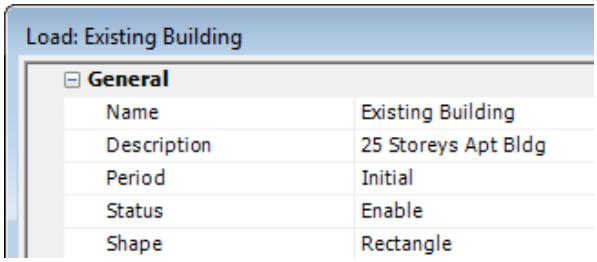
Due to the large number of records that may have to be imported into UniPile, there is no way to edit or enter these records manually at this time. When dealing with a few entries, we suggest entering the data in an ASCII text file, then, importing the data as described in Section 5.4 - Import SPT, CPT/CPTU Data. Once imported, data may be reset using the reset button located at the top of the window.

15. LOADS AND EXCAVATIONS

A user may add multiple loads and excavations applicable at different times during the project. Although loads and excavations are listed separately inside the data tree, the method used to specify loads and excavations is the same.

15.1 General

The entries located under this heading refer to the load and excavation under consideration.



Name
Use this entry to specify a name for the load (or excavation) under consideration. We suggest keeping this name short as it is used in the data tree and the various results windows and combo boxes.

Description
Use this to enter the description of your choice. This entry has no effect on the remainder of the results and is provided for information only.

Period
Defines the time at which this load (or excavation) applies. Options are Initial or Final.

Important
Starting with UniPile 5.0, a load (or an excavation) specified as "Initial" continues to exist beyond the "Final" period. If the scope of the load (or excavation) is meant to be temporary and removed after the initial stage of construction, a second negative image of the same load must be specified at "Final" condition. This concept is compatible with UniSettle 4.0.

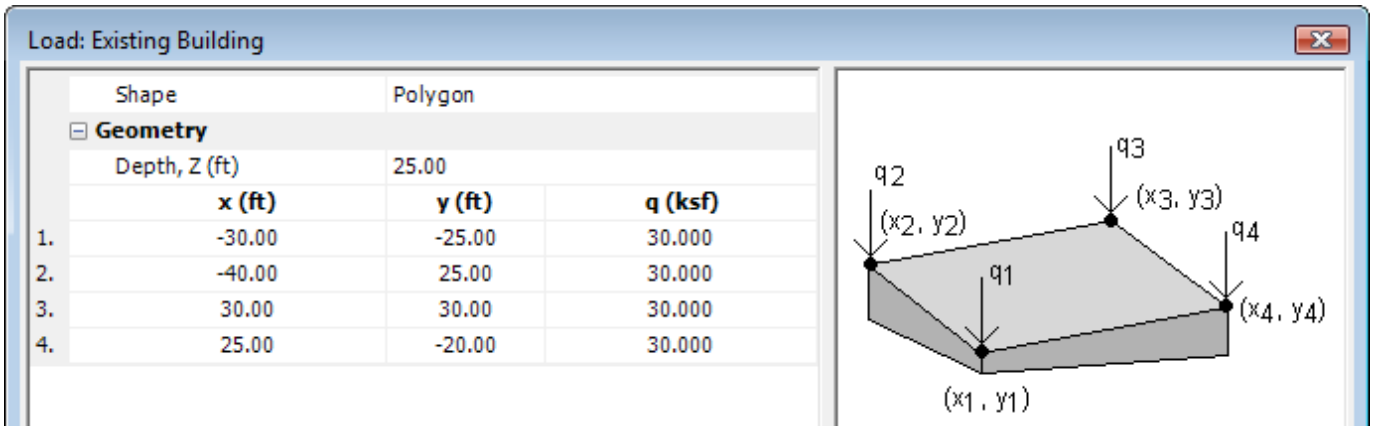
Status
Use this entry to temporarily disable a load (or excavation) from your analysis. Disabled loads and excavations appear on the site plan as a grey colour, rather than blue (load) or red (excavations).

Shape
Use this entry to select the geometric shape of the load or excavation under consideration. Available loads are Point, Line, Rectangle, Triangle, Circle, Polygon, Embankment (symmetrical or half), and Entire site. Available excavations are Rectangle, Triangle, Circle, Polygon, and Entire site.

Tip
- Point loads are the fastest way to model small footings.
- Line loads are the fastest way to model long and narrow footings and/or roads.
- Rectangular shapes are the most efficient way to model large loads or excavations.

15.2 Geometry

The entries available under this subject depend on the shape of the load (or excavation) under consideration. The following image shows the available entries for a polygon shape load.



Depth, Z
Defines the depth of the load or excavation under consideration. A load with a negative depth indicates a distance above ground (i.e. above the first soil layer). This feature may be used to define a new footing placed on a new fill, which in turn could be placed on top of the first soil layer.

Area, A
Defines the contact area when a point load is specified. This area limits the amount of total stress caused by the point load at the point of contact.

Breadth, B
Defines the breadth (or width) of a rectangular load or excavation. For a line load, breadth refers to the width of the line and limits the amount of total stress at the point of contact. For rectangular shape loads or excavations, breadth refers to the dimension measured along the East-West direction (X-Axis).

Length, L
Defines the length of a rectangular load or excavation. It refers to the dimension measured along the North-South direction (Y-Axis).

Radius, R
Defines the radius of a circular shape load or excavation.

Breadth, B_t
Defines the breadth (or width) measured at the top of an embankment shape load.

Breadth, B_b
Defines the breadth (or width) measured at the base of an embankment shape load.

Height, H
Defines the total height of an embankment shape load.

Density
Defines the density of the material used in the construction of an embankment. The total contact stress is calculated by multiplying the volume of the embankment by its density.

Load Q
The total load caused by a point load.

Load, q
The total contact stress applied by a load. For linear loads, q is expressed as load per length. For surface (area) loads, q is expressed as load per area.

X and Y Coordinates
These define the exact location and shape of the load or excavation. The exact representation of X and Y vary depending on the shape under consideration. Refer to the image associated with each type of load (or excavation) for details.

16. t-z/q-z FUNCTIONS

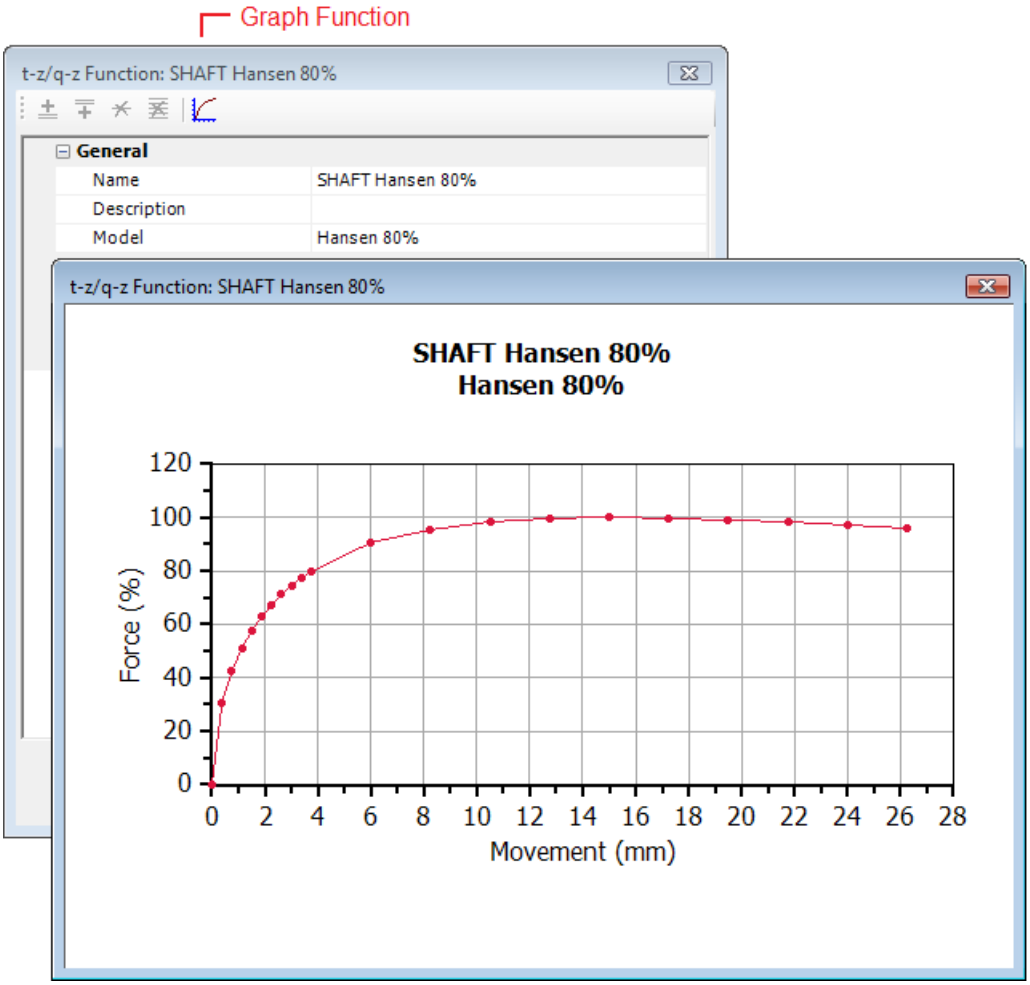
The load/transfer functions (t-z/q-z) are used in the static head-down and Bidirectional Cell loading test simulation. UniPile 5.0 allows multiple load/transfer functions and applies them to various soil layers. In addition to the 5 predefined models (Ratio, Chin-Kondner Hyperbolic, Exponential, Hansen 80%, and Zhang), users may also define their own model by specifying a series of movements and related resistance forces. The visibility and availability of some of the entries presented below vary depending on the selected model.

Important

The purpose of this section is not to explain each parameter in detail and how t-z/q-z functions relate to pile behaviour. For more information, we recommend that you refer to the "Red Book": Basics of Foundation Design by Bengt H. Fellenius, Dr. Tech., P.Eng., available online at
http://www.UniSoftltd.com/Uploaded/downloads/RedBook.pdf

16.1 General

The entries located under this heading refer to the t-z/q-z function under consideration.



Name
Use this entry to specify the name of the function under consideration. We suggest keeping this name short as it is used in the data tree and listed in the various soil layers next to the Shaft t-z/Toe q-z function feature.

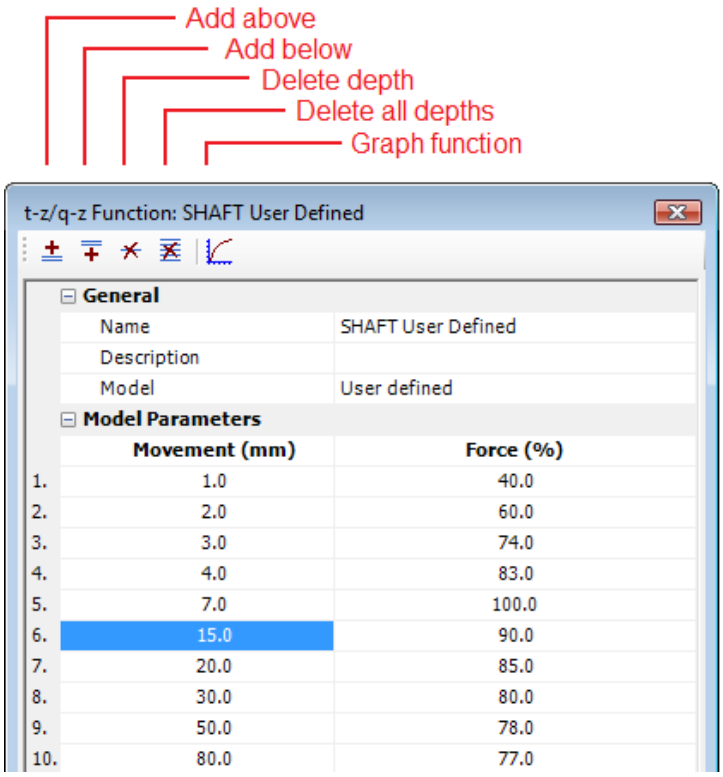
Important
Each time a new function is created, deleted, or modified, it automatically updates the list of available t-z/q-z functions available in each soil layer.

Description
Use this to enter the description of your choice. This entry has no effect on the remainder of the results and is provided for information only.

Model
Select between one of the available preset models: Ratio, Chin-Kondner Hyperbolic, Exponential, Hansen 80%, and Zhang or User defined model.

16.2 Model Parameters

The entries located under this heading are specific to the t-z/q-z model selected. The following image displays the input available when "User defined" model is selected.



Movement at r_u, δ_u
Use this entry to specify the movement (shaft or toe) at ultimate resistance or the movement at any specific resistance. The loading test simulation will stop at this movement value. Useful, in particular, when applied to the pile toe response.

Ratio Exponent
A ratio exponent ranging from a small value through unity. This value is used when the Ratio model is selected.

Zhang Coefficient, a
Use this entry to specify the Zhang independent coefficient.

Exponent Coefficient, b
Use this entry to specify the exponent coefficient. The exponent coefficient is required when the Exponential model is selected.

Slope, C_1
Use this entry to specify the slope of the straight line when the Chin-Kondner Hyperbolic or the Hansen 80% model is selected.

Ordinate Intercept, C_2
Use this entry to specify the ordinate intercept of the straight line when the Chin-Kondner Hyperbolic or the Hansen 80% model is selected.

Movement
Use these entries to define a series of movements when "User defined" model is selected. Additional rows may be added, deleted or inserted using the buttons located at the top of the window.

Force
Use these entries to define a series of loads when "User defined" model is selected. Additional rows may be added, deleted, or inserted using the buttons located at the top of the window.

Important
Each time a new function is created, deleted, or modified, it automatically updates the list of available t-z/q-z functions available in each soil layer.

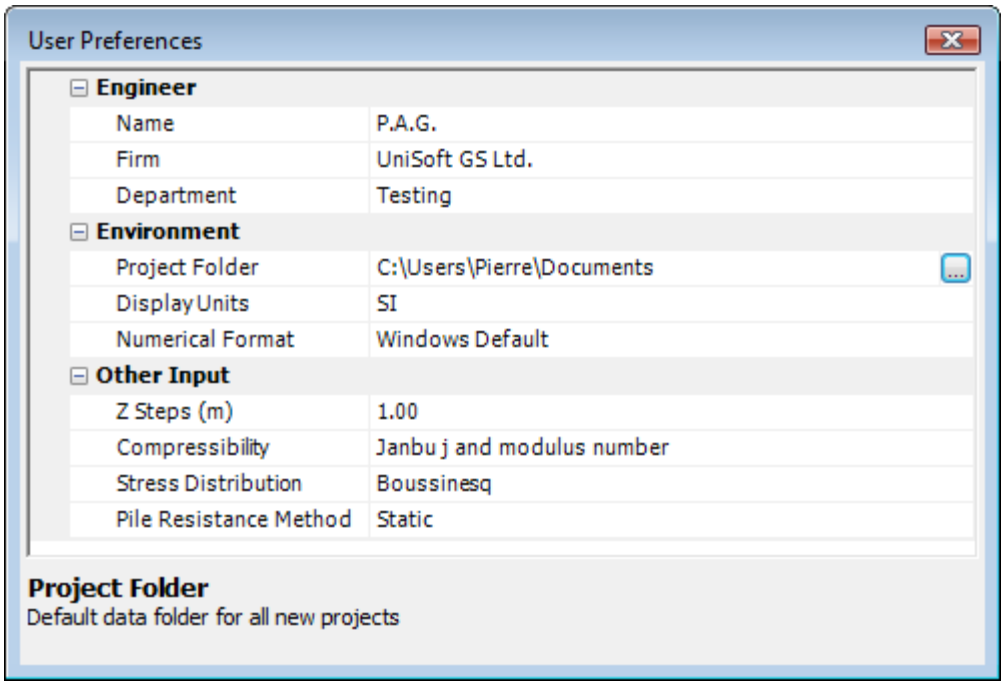
Important
Each time a new function is created, deleted, or modified, it automatically updates the list of available t-z/q-z functions available in each soil layer.

Important
For advice on how to enter the parameters of the t-z and q-z functions, refer to the "Red Book": Basics of Foundation Design by Bengt H. Fellenius, Dr. Tech., P.Eng., available online at http://www.UniSoftltd.com/Uploaded/downloads/RedBook.pdf.

Important
The load-movement response for residual load condition is different to that of a no-residual ("virgin") condition. For simulation of a static loading test under residual load condition, the fact that the initial portion of, in particular, the q-z function is re-loading must be considered. The same shape of the function cannot serve both the virgin and the residual load conditions.

17. USER PREFERENCES

User preferences are located under the main "Administration" menu and are used to personalize some aspects of the UniPile interface and defaults.



Important

Do not confuse these entries with those required by UniPile to perform the analysis. For example, changing the Pile Resistance Method to Eslami-Fellenius in this preference window will only affect the default value the next time the software is started.

This section of the manual provides a detailed description of the input variables used throughout the software. Some of the entries may not be available or visible to your specific interface as many are dependent on the version you are running.

UniPile 5.0 for Windows
Examples Manual

UniSoft Ltd.
Geotechnical Solutions

528 River Road
Ottawa, Ontario
Canada
K1V 1E9
www.unisoftltd.com

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UniPile 5.0 - Examples

The explanations of the several UniPile examples provided in the following assume that you, the Reader/User, has opened the particular UniPile example file and is engaging the various options along with reading the text.

Most examples are based on the SI-system of units. Please note that UniPile can be used equally well in the US customary units. For each example, a simple click on the "units button" will shift the system of units back and forth by hard conversion. To simplify the review for SI-challenged Users preferring to work in US customary units, Example 1 is provided in both systems and file "Demo Example 1 –- Test Pile_US.Unipile5" is prepared in a soft conversion from the SI-units file.

On completing the review of an example, practice using the program by changing one or a few inputs at a time and see the results unfold.

EXAMPLE 1 - TEST PILE

A 400 mm (16 in) diameter, 30 m (100 ft) embedment pile assigned a sustained (dead) load of 800 kN (180 kips) and a transient (live) load of 200 (45 kips) kN. The pile is assumed to be a test pile that will later be a part of the pile group of 32 piles with a footprint of 14.8 x 6.8 m (48.6 x 22.3 ft). Pile center-to-center spacing is 2.0 m (5 diameters).

The soil profile consists of a 25 m (80 ft) thick upper layer of clay, 10 m (30 ft) of sand, and a 25 m (80 ft) thick lower layer of clay. The groundwater table lies at a depth of 2.0 m (7 ft). The pore pressure distribution in the sand layer is hydrostatic and artesian with a 2.0 m (7 ft) rise above the ground surface. The pore pressure distribution in the clay layer is linear from lower to upper boundary of the layer (indicating no on-going consolidation).

In preparing the site for the static loading test, a 0.5 m (20 in) thick fill will be placed across the site. Later on, when all piles have been installed, the area outside the pile group will receive an additional 1.0 m (3.6 ft) of fill to a total height of 1.5 m (5 ft). No additional fill will be placed inside the pile group footprint.

The "Demo Example 1 - Test Pile_SI.Unipile5" file includes the above information and the additional input to use for the analysis of the test pile, i.e., the soil density and unit resistance values for shaft and toe. To simulate the response of the pile to a static loading test, the t-z and q-z functions are assumed (provided with the file).

Some basic information common for all analyses can be entered by selecting "Administration/user preferences" on the tool bar.

Background to the analysis methods is provided in the "Red Book" by Bengt H. Fellenius available for downloading from either [www.Unisoftltd.com], or from [www.Fellenius.net]. In order to limit the text length, and the reading effort, the term "self-explanatory" is used in a couple of places. If the item would appear less than "self-explanatory, the User is directed to the details on the item in the User Manual section.

Example 1 includes a CPTU-file. However, the file is only included for quick reference as the case is a made-up demo-case and the sounding and the soil data are from a different site. For CPTU analysis, see Example 2.

The "Tree"

All the required input options are initiated in the “tree” to the left. This example will concentrate on the basic "Tree" Steps of the input. It is assumed that SI-system of units is used. All pertinent input addressed in the "Tree" must be made before an analysis is performed.

"Tree" Step 1. The “General Input” options

The "Project Information" option allows for input of the particulars of the analysis and project.

The "Settings Option": UniPile calculates effective stress by subtracting the pore pressure from total stress. In some geologies, although this is rare, pore water can be salty and the water density, therefore, be than larger than that of ordinary water. The default value of unit water density is 1,000 kg/m^3 (62.43 pcf). The gravity constant is by default set to 9.81 m/s^2 (32.19.19 ft/s^2), but can be changed to any value, for example, 10 m/s^2.

The analysis in UniPile considers two separate site conditions, called “periods”: “Initial” and “Final”. The soil profile used is always the same for either period. However, fills, loads, and excavations can be different. Note, fills, loads, and excavations that are input for “initial”, if not present at “final”, must be 'removed'. The easiest way to 'remove' is to input a negative load over the same area counteracting the “initial” condition. The User can copy and paste the load to remove and add a negative sign to the pasted copy. To remove an excavation from the “final” condition, check the effective stress (σ') at the depth equal to the bottom of the excavation for the "initial" condition and add a load with that stress over an equal area for the “final” at the depth of the excavation.

Stress distribution includes the effect of fills, load, and excavations and can be by 2(V):1(H), Boussinesq or Westergaard. The ”Settings” option is also where the User decides to include or disregard residual load (not a part of Example 1; for details, see Example 2) and where the User can limit the extent of the pile toe movement in a static loading test. If the test is performed by a bidirectional test, this is where the depth of the cell is input; 28 m (30 ft) in Example 1.

The method for calculating the pile resistance can be static (total or effective stress or both combined).

When using UniPile to analyze results of a static loading test on an instrumented pile, the ”Depth Points” option allows the User to input the depths to the gage levels in the pile and have UniPile calculate the loads at these depths. (As Example 1 does not include gage records, no such depth points have been input).

"Tree" Step 2. The “Pile Data” option

The “Pile Data” option is where all pile information is input. Most input is self-explanatory. “Transition height” indicates the distance from fully mobilized negative skin friction to fully mobilized positive shaft resistance (for details, see the User Manual, Section 10.1). The pile geometry (”Longitudinal Profile”) is by default “Uniform”. Click anywhere on the ”Longitudinal Profile” row and the alternative of irregular profile (“User defined”) pops up with a table for input of depth and shape changes. Click on the row for “Cross Section” and several options for the pile shape pops up, including “User defined”. The input shape for Example 1 is “square”.

The “Group” option is next and the input is self-explanatory. Note that UniPile provides three options of depth to the “Equivalent Raft”: It is either the depth to the Neutral Plane, as determined in the UniPile calculation, to the pile toe, or to a “User defined” depth that is independent of the UniPile calculation. The load or stress over the pile equivalent raft will be included in the settlement analysis as acting at the "Final" condition. (The load or stress is not included in the analysis of effective stress for the pile load distribution at the “final” condition). If the

equivalent raft placed anywhere else than at the pile toe, the width and breath of the raft must consider the distribution between the raft depth and the pile toe. The "Red Book" suggests that the raft size be determined from widening its sides by 5(V):1(H) from the raft to the pile toe. See also theStep-4 comment on including the effect of the pile stiffening on the compressibility between the raft and the pile toe.

"Tree" Step 3. The "Soil Layers" option

The Soil Layer Option is explained in the User Manual Section 12. The soil profile input is by one layer after the next. If settlement analysis is by means of the conventional C_c-e_0, the void ratio (e_0) needs to be input on the row below the density input. "Resistance Parameters" for "Effective stress analysis is by input of the Bjerrum-Burland beta-coefficient, ß. Total stress, α-method) input is by unit "Shaft Shear Strength". If an α-coefficient is desired, it must be applied to the shear strength value before making the input. Note that the analysis can be made with input of both ß and shear strength values, if so desired. The unit toe resistance can be input either as a unit resistance (stress) value or an N_t-coefficient; the former is the default option.

The "Resistance vs. Movement" refers to the stress-movement or load-movement response of the soil. The response of shaft resistance is indicated as "t-z Function" and toe resistance response as "q-z Function". Design of the appropriate function for each layer is carried out at the last option of the tree, the "t-z/q-z Functions".

The input to settlement analysis is made under "Compressibility" and consists of option for Janbu method, or for conventional C_c-e_0 or E-modulus approaches. The settlement analysis does not include calculation of settlement with time (consolidation). For consolidation analysis, the User needs to export the soil profile and loads to UniSettle. Settlement calculation is made assuming that the "initial" condition is, well, the initial condition, and the change of effective stress between the "initial" and "final" conditions is applied to the settlement calculation.

The settlement within the pile depth is minimal due to the stiffening effect of the piles. Therefore, when calculating the settlement for a pile group, the soil compressibility should be input as the stiffened compressibility, that is, it is proportioned between the soil compressibility (modulus) and the pile material modulus (proportioned to the respective areas of soil and pile). Usually, one can avoid this adjustment by placing the Equivalent Raft at the pile toe. Placing the Equivalent Raft a the pile toe (and not adjusting the soil compressibility for the pile stiffening effect also means that the calculated settlement distribution is representative for the soil settlement immediately outside the pile group. Detailed settlement calculation, including development over time, needs to be performed in UniSettle.

"Tree" Step 4. The "Pore Pressure" option

The pore pressure input is self-explanatory. It can be input as hydrostatic or non-hydrostatic with specific distribution. UniPile allows calculating for Initial Period or Final Period, and the pore pressure, therefore can be input as "Initial Pore Pressure" and "Final Pore Pressure". Note that when the cursor is placed on a row in the table, the menu-bar in the table is activated and allows adding or deleting a row.

"Tree" Step 5. The "SPT, CPT/CPTU Data" option

For comments on the "SPT, CPT/CPTU Data" option, see Example 2.

"Tree" Steps 6 and 7. The "Loads" and "Excavations" option

The input for loads and excavations is self-explanatory.

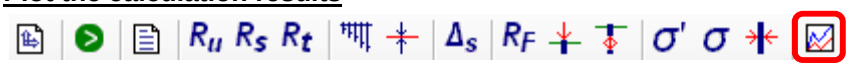
"Tree" Step 8. The “t-z/q-z Functions” option

UniPile provides five different relations (functions) for input of t-z and q-z function (the Ratio, Chin-Kondner hyperbolic, Exponential, Hansen 80 %, and Zhang Functions) and a sixth approach, which is a “User defined” curve. For details on these, see the “Red Book” and Page 10 below. The functions are prepared the 100-% value being the input for "ultimate resistance". The primary input is the movement that generates the assigned ultimate resistance. Note, where the shaft resistance is strain-softening, the maximum load calculated for the loading test may be smaller than the calculated capacity using the input shaft and toe "ultimate" resistance values. This is because the strain-softening has reduced the maximum force along a pile element close to the pile head before the maximum force at an element close to the pile toe has developed.

The site plan

The lay-out in plan of pile, pile group, and loads and excavations can be seen by clicking or

Plot the calculation results

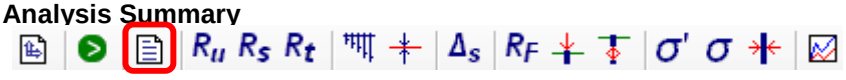


All results tables can be shown as plotted graphs by clicking on the far right ico

Perform calculation

To perform the calculation—to analyze—click on the green circle, " "a on the tool bar or choose "Analysis ". The results of the UniPile calculations are accessed by clicking on the specific button and are presented in a series of tables and graphs. All graphs can also be produced—combined—in Excel from the tables after exporting them to a text file. Note, result tables exported to an Excel sheet are saved per the Excel general format and need to be brought to Excel number format before use in plotting or calculations. This is simply done by writing the number "1" in a free cell and then copy (crtl+C) the number and pasting it using "Paste Special\Multiply" over all of the table values. Each table and graph can be exported individually as a tab-delimited text file or a jpg-format graph file for later insertion into a report or other document. Individual tables, so exported, can be input to an Excel file for separate plotting.

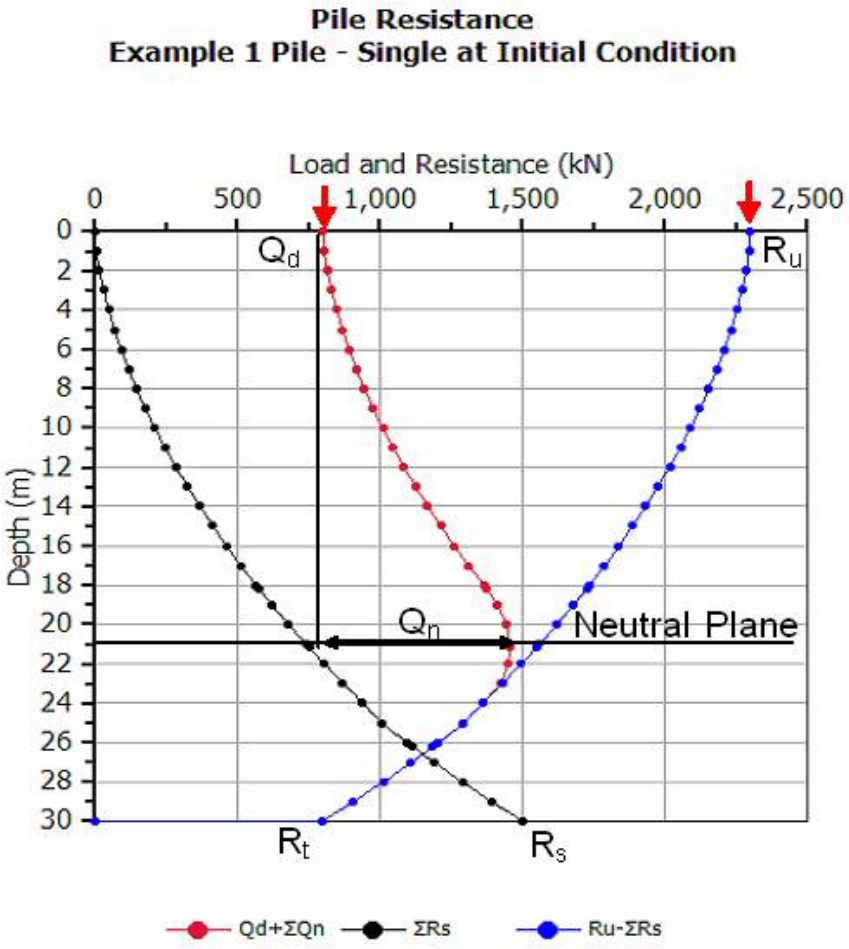
Analysis Summary



Click on the rectangle next to the green circle " "and the "Analysis Summary" will appear, listing amongst other information, the Total Resistance (pile capacity) and the shaft and toe resistances plus depth to the neutral plane and magnitude of the drag force and the maximum force in the pile. The summary can be called up at any time by clicking on the symbol " ".

Load and Resistance Distribution

Click on the square with the symbol "**R_u**" and a table; will appear headed "Pile Resistance" (the load and resistance distributions). Click next on the far right symbol "" and the data in the table will be shown in a graph, as shown below. The graph shows (blue curve) the distribution curve for the ultimate resistance (pile capacity) calculated for the input resistance values, (black curve) the distribution of the ultimate shaft resistance, and (red curve) the long-term load distribution when the Neutral Plane has developed. The bending of the curve reflects the height of the transition zone.



Where Q_d is the assigned dead load, R_u is the calculated ultimate resistance, R_s and R_t are the calculated shaft and toe resistances, respectively, and Q_n is the calculated drag force. The curve "R_u-ΣR_s" is the load distribution calculated for the input of "ultimate" shaft and toe resistance values, say, as would be measured in a static loading test . The curve "Q_d+Q_n" is the long-term load distribution. For the example case, it is assumed that the pile is subjected to maximum negative skin friction. If the transition height is increased from the current 3 m to a larger value, the drag force reduced.

The table, like all result stables, can be exported as a text file and the graph, like all graphs, can be exported as a jpg-format graphic file in the axis ratio prepared on the screen.

Shaft Resistance Distribution

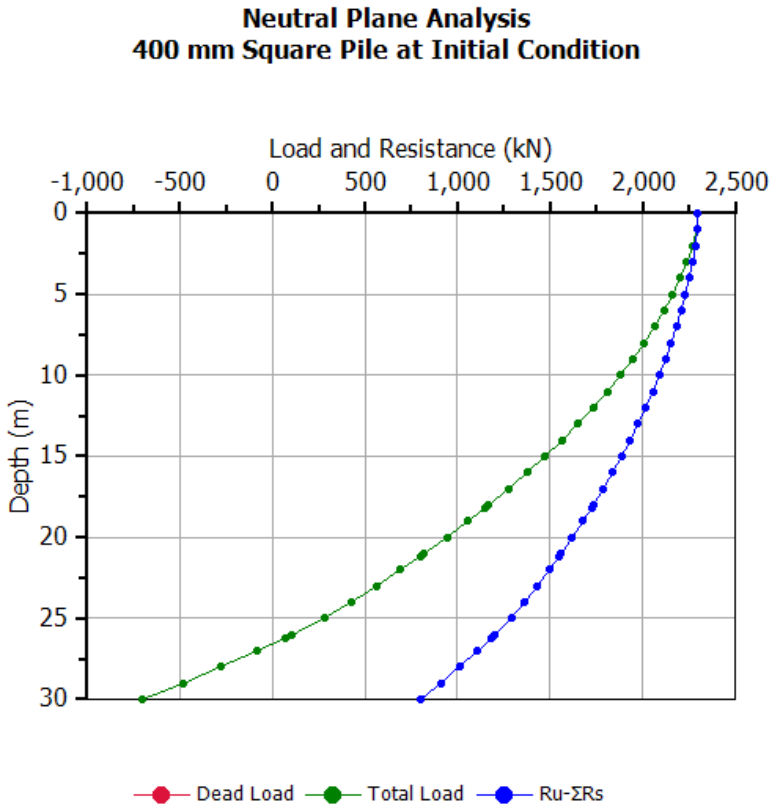
Click on the square with the symbol "**R_s**" and a table; will appear headed " Shaft Resistance". Click next on the far right symbol " " and the data in the table will be shown plotted in a graph.

Embedment Analysis and WEAP Input

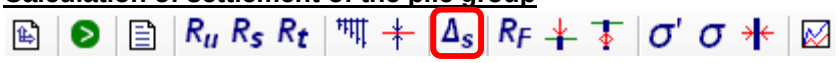
Click on the square with the symbol " " and a table will appear headed " Embedment Analysis". Click next on the far right symbol " " and the data in the table will be shown in a graph. The data in the table will be useful as input to a wave equation analysis using the WEAP program. Export the table to a text file and print, or clip and paste as desired.

Neutral Plane Analysis

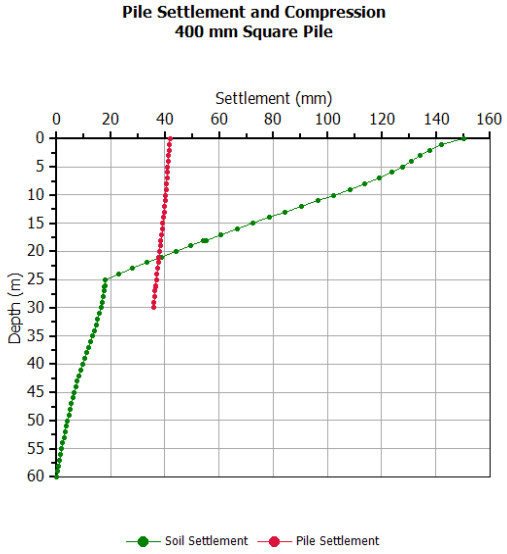
Click on the square with the symbol " " and a table will appear headed "Neutral Plane Analysis". Click next on the far right symbol " " and the data in the table will be shown plotted in a graph, as follows. The green line in the graph shows the depth of the neutral plane for the dead load applied to the pile head. In the example case, the 800-kN dead load results in 21.2 m depth to the neutral plane. This option can be useful when pondering what maximum dead load to assign and still have a neutral plane in non-settling soil.



Calculation of settlement of the pile group

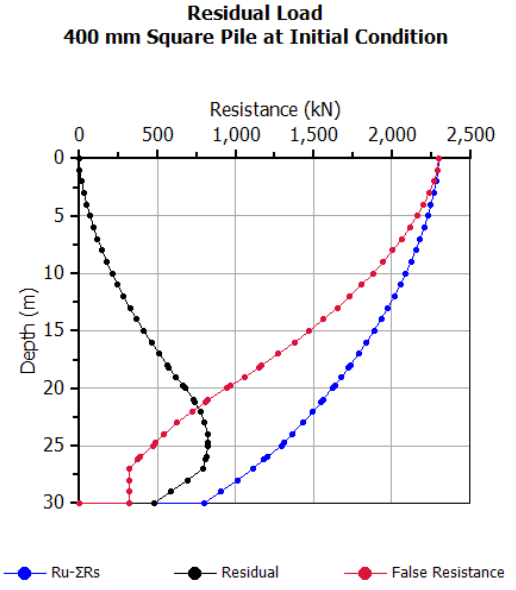


Click on the square with the symbol "Δ_s" and a table will appear headed "Pile Settlement and Compression". Click next on the far right symbol "" and the data in the table will be shown plotted in a graph, showing the results of the calculation of the soil and pile settlements due to the load on the equivalent raft and the fill, as shown below,. The pile settlement is the red line crossing the green soil settlement curve. It is sloping as determined by the pile compression for the axial load.

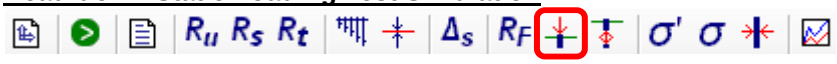


Residual Load Analysis

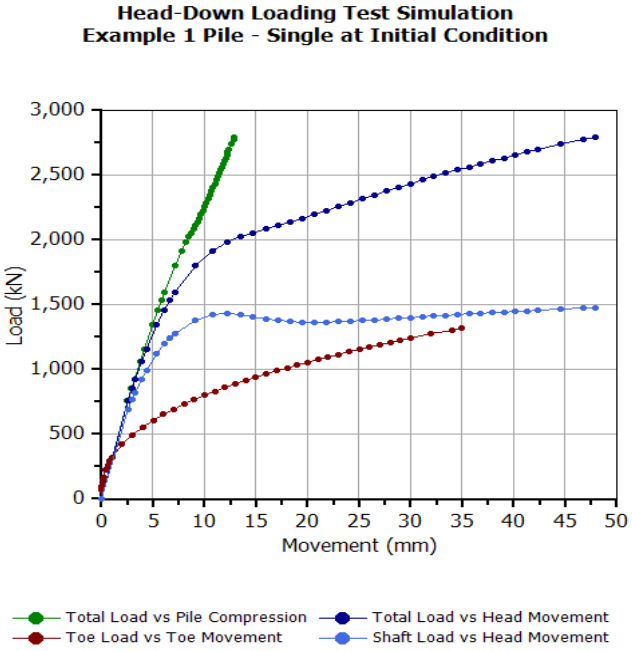
Click on the square with the symbol "$\mathbf{R_F}$" and a table will appear headed "Residual Load". Click next on the far right symbol "" and the data in the table will be shown plotted in a graph, as shown below. The black line is the distribution of residual load as per the input. The blue curve is the true load distribution as if there had been no residual load affecting the static loading test (and any gages along the pile). The red line is the false resistance representing the distribution shown by the gages without correction for residual load—"the false resistance".



Head-down Static Loading Test Simulation



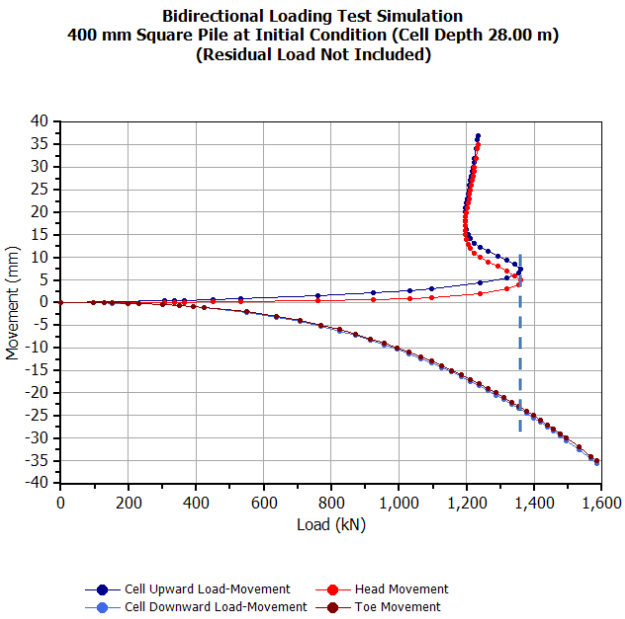
Click on the square with the symbol " " and a table will appear headed " Head-down Static Loading Test Simulation". Click next on the far right symbol '" and the data in the table will be shown plotted in a graph, as shown below. The graph includes the load-movement curves of the pile head (dark blue), the pile-toe (dark red), the pile shaft (light blue curve), and the pile deformation or shortening (green). The calculation extent is controlled by the pile toe movement, here limited to 35 mm (as input under "Settings"). The pile toe movement vs. pile head movement (as would be measured by a toe telltale) is not included here, but can be output if desired (default option, actually).



The calculations have been carried out much beyond the loads and movement usually involved in a static loading test. Moreover, it is assumed that the pile is unaffected by residual load. To see how residual load would affect the analysis, go to Settings/Residual Load and input 100 % shaft resistance, meaning fully mobilized shaft shear for residual load in both negative and positive directions, i.e., above and below the neutral plane) and a transition height of 5 m (Note, it need not be the same as the transition height for the long-term service condition of the pile). Residual load is more fully discussed for Example 2. It is particularly enlightening to see how residual load will affect the results of a bidirectional loading test.

Bidirectional Static Loading Test Simulation

Click on the square with the symbol " " and a table will appear headed " Head-down Static Loading Test Simulation". Click next on the far right symbol '" and the data in the table will be shown plotted in a graph, as shown below. The graph shows the results of the simulation of a bidirectional static loading test on the Example 1 pile carried out beyond the maximum load of an actual test (actual test limit is indicated by the dashed line). The option of "Shaft Buoyant Weight" is set to "include", which represents the test condition and the cell measurements in a test. The cell test simulation is useful for planning where to place a cell in a test pile and for back-calculating soil parameters representing the test results.



The bidirectional test starts by "breaking the bond" at the cell level, that is, the expansion of the hydraulic jack separates the bottom plate of the cell from the rest of the cell. This creates an opening across the pile at the cell level letting water into the "crack" To ensure that the pore pressure acts is independently of water seeping in from outside the pile, the cell arrangement includes a small-diameter, water-filled pipe from the pile head (ground surface) to the cell level.

Initially, the water pressure at the cell level is the pressure head from the cell level to the groundwater table, which in most cases would lie some distance below the ground surface (and the pile head). However, as the test proceeds, after the first couple of test increments, the level in the water pipe stabilizes, which means that the water pressure at the cell level becomes more or less equal to the pore pressure at the cell level.

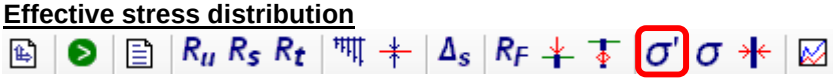
The water pressure acting across the pile section at the cell level has two effects. First, it reduces the weight of the pile that the cell load has to overcome before bringing about any upward movement is reduced to the buoyant weight. Second, the pressure results in a water force assisting the cell in pushing downward.

The UniPile "Settings/Shaft Buoyant Weight" set to "Include" is the simulation of the test conditions. However, The load-movement curves can be calculated showing the cell loads minus the water-pressure effect by setting the option to "Disregard". The "Shaft Buoyant Weight" setting has no effect on the simulation of the head-don static loading test.

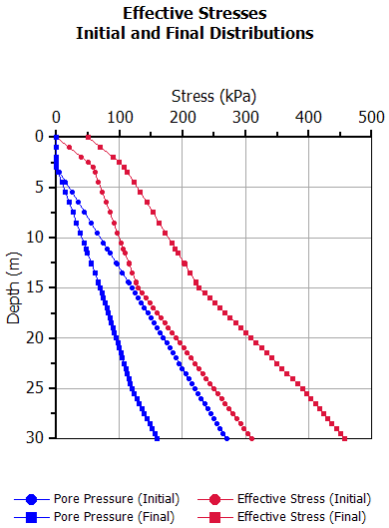
By trying out different cell depths, the User can find the depth that provides the balance between the upward and downward load-movement curves. The above graph is calculated for a cell depth of 28 m and a 35-mm pile toe movement. A balance between the upward and downward load-movements can either be achieved with a 29-m cell depth or by limiting the analysis to a pile toe movement no larger than 23 mm.

UniPile calculates the upward and downward responses independently of each other. To simulate an actual test, after the first calculation round, go to "Settings" and change the "Max. toe moment" input from 35 mm to 23 mm, which is the downward movement for which the upward curve reached maximum load, 1,360 kN, calculated for an upward movement of 6.5 mm. The output graph will now look more similar to an actual test, which, of course, has to stop once the pile's upward thrust fails.

Effective stress distribution



Click on the square with the symbol 'σ'' and a table will appear headed " Head-down Static Loading Test Simulation". Click next on the far right symbol '" and the data in the table will be shown plotted in a graph, as shown below.

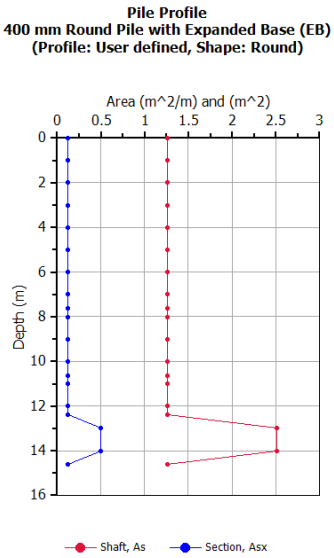


Total stress distribution

Click on the square with the symbol 'σ' and a table will appear headed " Head-down Static Loading Test Simulation". Click next on the far right symbol '" and the data in the table will be shown plotted in a graph.

Pile profile

Click on the square with the symbol '" and a table will appear headed " Head-down Static Loading Test Simulation". Click next on the far right symbol '" and the data in the table will be shown plotted in a graph as shown below.



CONFIGURING t-z and q-z FUNCTIONS

UniPile includes five t-z and q-z functions for simulation of the pile load-movement response. Each soil layer can be assigned a different function. Each "t-z/q-z" option shows an input screen and a graph of the force (%) and movement (mm or inch) and each is are correlated to the chosen inputs of soil layer resistance. The 100-% value of the force ("r_u") is the "ultimate" and the "δ_u" is the movement for that force. (The r_u and δ_u shown on the screen should more rightly be denoted r_{100} and δ_{100}, because, they do not stand for the "ultimate", but indicate the resistance for the various soil elements within a soil layers and the movement for that resistance. In the five formulae, they are referred to as Q_n and δ_n).

All functions require input of the maximum movement value to show in the function graph and all functions, but the exponential, require input of the movement, δ_u, for which the soil layer resistance (100 %-value) occurs. Thus, all curves will pass through the 100%/"δ_u" point. The additional input to choose for the various functions determines the shape of the curve on both sides of the100-% point.

The **Ratio Function**,

The Ratio Function is a strain-hardening response independent of any ultimate load.

$$Q_n = Q_S \left(\frac{\delta_n}{\delta_S} \right)^{\theta}$$

where Q_n = any applied load
δ_n = movement for Q_n
Q_s = any other applied load
δ_s = movement for Q_S
Θ = exponent

The Ratio Function input is the value of the exponent, Θ, which theoretically goes from 0 through unity. Usual ranges are 0.1 through 0.5 for shaft resistance and 0.4 through 0.8 for toe resistance. An exponent equal to 1.0 represents a straight line—elastic soil response. When using the function to fit, say, an actually observed pile-toe load-movement curve, the User will first have to input a toe resistance (at the soil-layer input screen) that produces a calculated toe resistance equal to 100 % of that measured at a certain toe movement δ_u, whichever movement the User now prefers to input as the 100-% movement. The User then activates "Analyze", selects the "Head-down loading-test simulation" for view. The display of the calculation results for the pile toe load-movement will be used to verify agreement between the measured and calculated values of load and movement. Of course, there will at first be little or no agreement between the measured and calculated load-movement curves. The user now adjusts the exponent and repeats action until the measured and calculated curves agree. It may well be that no exponent will provide full agreement. If so, the User selects another t-z/q-z function for fitting.

The Hyperbolic Function

The Hyperbolic Function is strain-hardening response based on the Chin-Kondner relation.

$$Q_n = \frac{\delta_n}{C_1 \delta_n + C_2}$$

$$Q_\infty = \frac{1}{C_1}$$

$$C_2 = \delta_n\left(\frac{1}{Q_n} - C_1\right) \quad = \delta_n\left(\frac{1}{Q_n} - \frac{1}{Q_\infty}\right)$$

Where Q_n = any applied load
Q_u = load at infinite movement
δ_n = movement for Q_n
C_1 = slope of the straight line in the δ/Q versus δ_n diagram
C_2 = y-intercept of the straight line in the δ/Q versus δ_n diagram
Q_∞ = resistance at infinite movement

The Q_u refers to the ultimate resistance at infinite movement. However, the ultimate is usually referred to as 100 % of the value mobilized at a finite movement; 5 mm is a commonly used value for unit shaft resistance along a pile element. At whatever finite 100 % movement assumed, the inverse of the coefficient C_1 indicates the ratio (%) of load to the 100 % of the resistance at infinite movement.

Similar to the other functions, applying the Hyperbolic Function starts by entering a movement value to represent the soil layer input of resistance, the 100-% value. The input of the "Slope, C_1" governs the shape of the curve. A C_1-value of 0.100 represents a constant 100-% resistance, which is not a meaningful input—the C_1-value must always be smaller. For example, a 65-mm toe movement for the 100-% input resistance and a C_1-value of 0.0098 will result in a q-z curve that reaches about 80 % at a toe movement of 5 mm. In contrast, a movement input of 10 mm together with a C_1-value of 0.0075 will also result in a q-z curve that reaches about 80 % at a toe movement of 5 mm, but the load at 65 mm will be 127 %. The former is almost "elastic-plastic" response, while the latter is a strain-hardening response.

The **Exponential Function**

The Exponential Function is an approximately elastic- plastic response based on the Van Der Veen relation.

$$Q_n = \quad Q_S(1 - e^{-b\delta_n})$$

Where Q_n = any applied load
δ_n = movement for Q_n
Q_s = any other applied load
b = an exponent

The Exponential Function applies to shaft resistance modeling of cases where the response is almost elastic-plastic. The advantage of the Van Der Veen's function is that the kink between the elastic and plastic lines is smoothened over. The rise of the curve is at first almost vertical until close to the 100-% value where the curve changes to a horizontal (plastic) line. The exponent, b, governs the curvature and the distance before the horizontal line.

The **Hansen 80-% Function**

The Hansen 80-% Function is a strain-softening response and applies primarily to shaft resistance modeling.

$$Q_n = \frac{\sqrt{\delta_n}}{C_1\delta_n + C_2}$$

$$Q_u = \frac{1}{2\sqrt{C_1 C_2}}$$

$$\delta_u = \frac{C_2}{C_1}$$

Where Q_n = any applied load
Q_u = ultimate load
δ_n = movement for Q_n
δ_u = movement for Q_u
C_1 = slope of the load-movement curve plotted as $\sqrt{\delta_n}/Q_n$ versus Q_n
C_2 = y-intercept of the $\sqrt{\delta_n}/Q_n$ versus Q_n

Similar to the exponential function, the Hansen Function is almost exclusively used for shaft resistance response. The shape of function curve is controlled by the movement and the C_1-inputs (note, the C_1 of the Hansen function is defined somewhat similarly to that of the Ratio Function, it is not the same). In fitting calculations to actual measured values, the User decides which movement occurred when the ultimate soil resistance occurred, i.e., the peak value and the shape of the curve before and after this value. Note, however, that the movement and C_1 are interrelated. Change one and the other changes too.

For the Hansen function, regardless of the input of δ_u, Q_u, and C_1, the movement for the 80-% of Q_u is always 0.25 of the δ_u, movement.

The **Zhang Function**

The Zhang Function, is a strain-softening response that also applies primarily to shaft resistance modeling.

$$Q_n = \frac{\delta_n(a + c\delta_n)}{(a + b\delta_n)^2}$$

$$Q_n = \frac{1}{4(b - c)}$$

$$\Gamma = \frac{c}{Q_n b^2}$$

Where Q_n = any applied load
δ_n = movement for Q_n
a = constant
b and c = constants or factors that depend on a, Q_n, and δ_n
Γ = resistance at infinite movement (must be >0)

The input selected for "δ_u" and "a" determines the factors "b", "c", and Γ used by UniPile.

$$b = \frac{1}{2Q_n} - \frac{a}{\delta_n}$$

$$c = \frac{1}{4Q_n} - \frac{a}{\delta_n}$$

The Zhang Function produces a t-z curve very similar to the Hansen curve. As for the other functions, the movement for which the peak resistance (100 %) is observed is input first. The coefficient "a" is then used to adjust the shape of the curve to fit.

EXAMPLE 2 - SANDPOINT

Example “Demo Example 2 - Sandpoint.Unipile5” is from a full-scale test on an instrumented 45 m long pipe pile with a 44 m embedment. The case is published: Fellenius, B.H., Harris, D., and Anderson, E.G., 2004. Static loading test on a 45 m long pipe pile in Sandpoint, Idaho. Canadian Geotechnical Journal 41(4) 613-628. The example is used to illustrate the analysis using a cone penetration sounding, analysis for residual load, and settlement.

The loads measured in the static loading test for the plunging failure of the pile at the applied load of 1,900 kN at the depths of the gage levels are listed in “General Input/Depth Points”.

The soil profile consists of three layers: 9 m of sand followed by 41 m of clay on 3 m of sand, which are deposited on clay and silt to large depth, as detailed in the file. The groundwater tale lies at a depth of 4.5 m and the pore pressure distribution is hydrostatic. The soil input includes compressibility parameters. Janbu method is applied.

The CPTU data of the case are already imported to the Example 2 UniPile file. The CPTU data are from a sounding pushed close to the location of the test pile with readings taken every 50 mm. The pile capacities determined by the various CPT/CPTU methods of analysis (chosen from “Settings/Pile Resistance Method” vary widely (from about 900 kN through about 4,000 kN). The 1,900-kN capacity ("total Resistance") calculated using the Eslami-Fellenius method is very close to the plunging capacity found in the static loading test, also1,900 kN.

The UniPile calculation results using the cone sounding data include the equivalent average beta-coefficients within the depths defined by the “step” assigned for each soil layer. For each cone reading, a beta-coefficient is obtained by, first, calculating the unit shaft resistance (according to the applicable method) and, then, dividing this value by the effective stress at that depth.

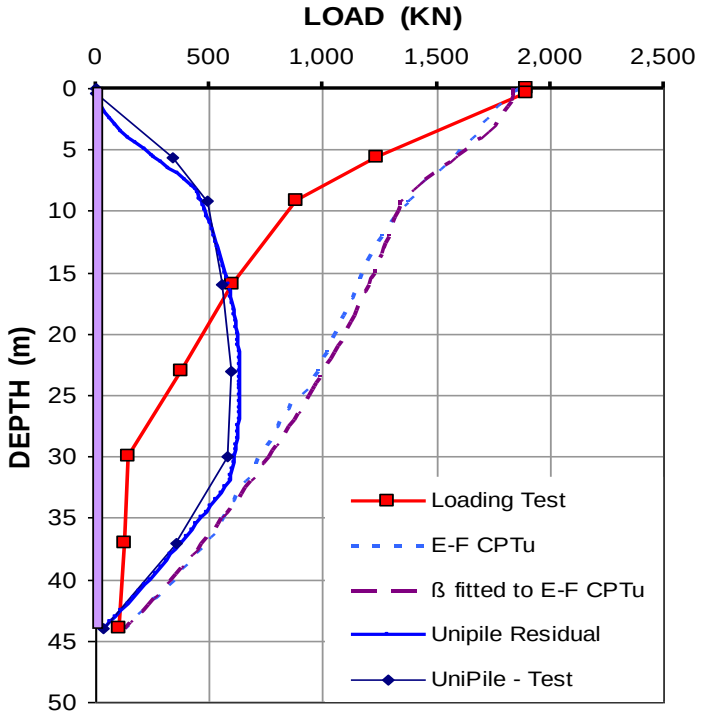
The equivalent beta-coefficients resulting from the E-F analysis were used to find—by trial and error—the distribution of beta-coefficient that fitted an effective stress analysis to the E-F analysis and the maximum test load. The match to the E-F method distribution was restricted to not splitting up the soil layers and only having a beta-coefficient at the upper and lower boundaries of the soil layers. The so-fitted beta-coefficients are those used as input to the Example 2 UniPile file. To see the beta-coefficient input, select the "Resistance Method" as "Static" at the "General Input", "Settings" option.

The measurement of load distribution in the pile showed that the pile was strongly affected by residual load, as described in the mentioned paper. The large reduction of load along the upper length of the pile indicates presence of fully mobilized negative skin friction and the absence of load change in the lower length of the pile indicates fully mobilized positive shaft resistance (the test cannot mobilize any shear beyond that mobilized by the residual load). Adding the residual load to the measured distribution (the “false” load distribution) results in the “true” load distribution. The three distributions: measured, residual, and “true” are interrelated; any two will determine the third.

The load measured at the bottom of the sand layer is about 900 kN. Indicating that the shaft resistance would be about 1,000 kN. If fully mobilized residual load was present in the test pile, then, the residual load would be half of the 1,000-kN value and the “true” resistance would be about 1,400 kN, which is very close to the 1,390-kN value indicated by the CPTU analysis. Down to about 30 m depth, the E-F load distribution is very close to the “true” distribution determined by assuming that the measured distribution was affected by fully mobilized residual load. Therefore, the analysis of the example has assumed that the effective stress analysis matched to the CPTU E-F results represents the “true” load distribution in the pile at the maximum test load.

The UniPile tables presenting the results of the calculations were exported to text files that were imported to Excel for plotting in a diagram together with the measured load distribution. The difference between the effective stress distribution (ultimate resistance by the ß-method) and the measured distribution (static loading test) is the residual load present in the pile at the start of the static loading test. The distribution of the residual load is close to that shown in the mentioned paper, but for the 7-m length nearest the pile toe. (The here presented analysis shows a smaller toe resistance than that found by the authors of the paper. The analysis in the paper focused on the extrapolation of the effective stress analysis per the method detailed in the Red Book).

The below diagram shows the distributions of the measured loads ("Loading Test"), the CPTU E-F method ("E-F CPTU"), the effective stress analysis ("ß fitted to E-F CPTU"), and the residual load ("UniPile Residual") calculated by UniPile. The fifth curve ("UniPile - Test") is the residual load determined by subtracting the measured loads from loads of the loads of the effective stress analysis. The difference between "UniPile Residual" and "UniPile - Test" is a measure of the agreement between the methods. It could be fine-tuned by adjusting the percentage of residual load mobilization and height of transition height ("Settings/Residual Load"). However, this would essentially be only for cosmetic reasons. The agreement shown is remarkably good.

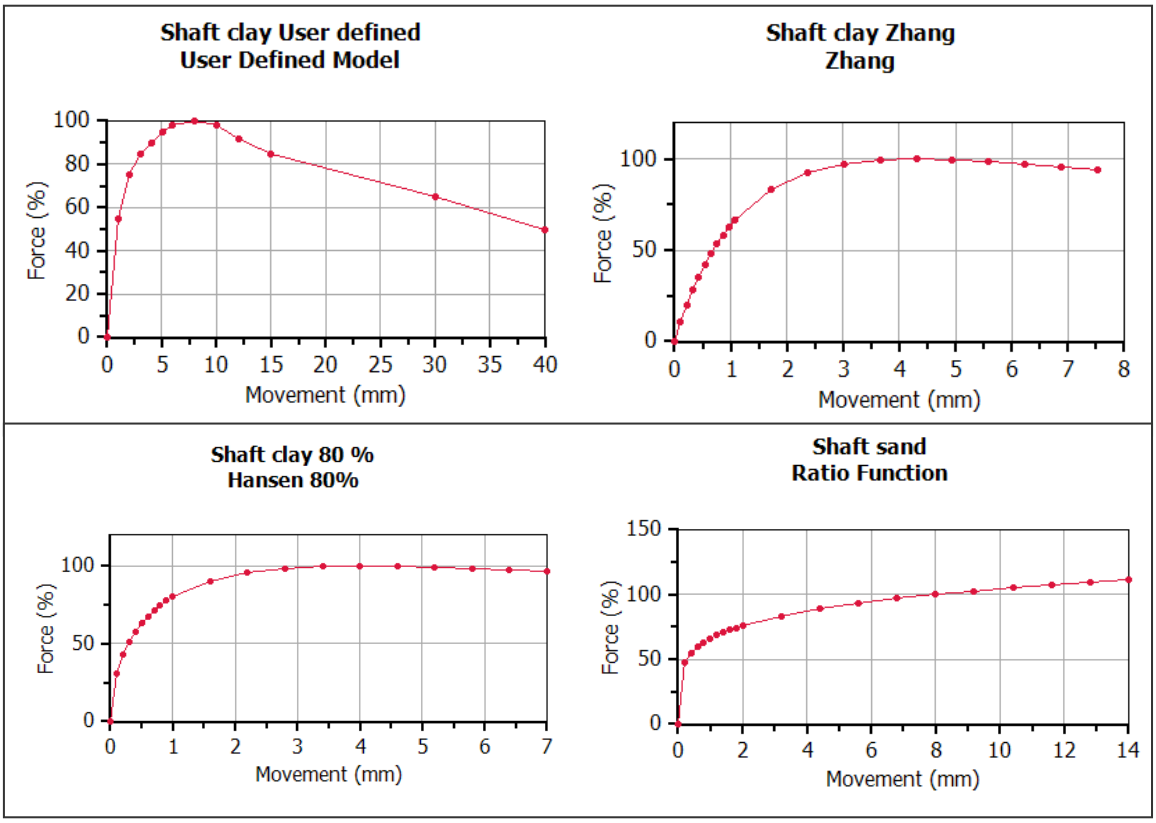


A series of trial-and-error simulated static loading tests was used to determine the best fitting t-z and q-z functions for use in simulating the static loading test. A "user defined" shaft resistance (t-z function) was found to be the best fit for the shaft resistance in the clay layer. Alternatively, the strain-softening Zhang Function is used in a shape that closely follows the "user defined" curve. The Zhang method includes an input coefficient, "a", which value controls the degree of strain-softening after the peak (100 %) shear resistance is mobilized. It can range from 0.0000 for no strain-softening, through 0.0100 for loss of all (100 %) of shear resistance at large ("infinite") movement. An "a' equal to 0.0083 corresponds to a 50-% reduction at a large movement. The fit for Example 2 was obtained by assuming ultimate resistance occurring at a movement of 4.3 mm combined with an "a"-coefficient of 0.0098.

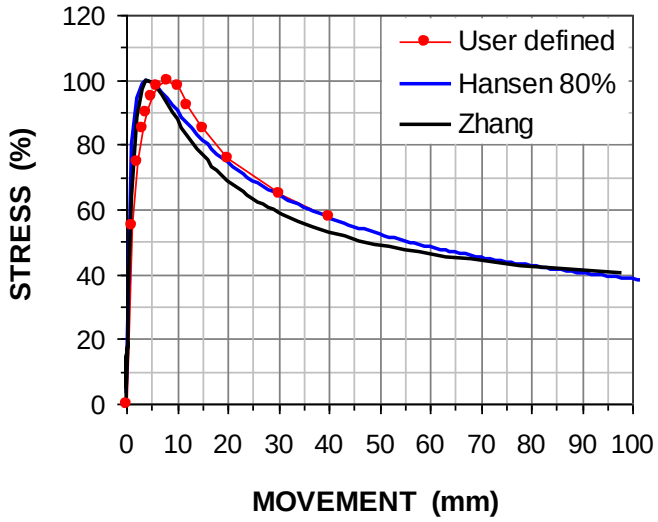
The fit was also made for the Hansen 80-% t-z function. It was achieved for a peak value occurring at 4 mm pile head movement. In contrast to the Zhang method, the Hansen method does not include the means for adjusting the shape of the t-z curve after the peak.

For the shaft response (t-z) in the sand, the Ratio Function was used with an 8 mm movement at the ultimate shaft resistance and an exponent of 0.200. For the toe resistance in the clay, the q-z function was the Ratio Function with a toe movement of 25 mm and an exponent of 0.5.

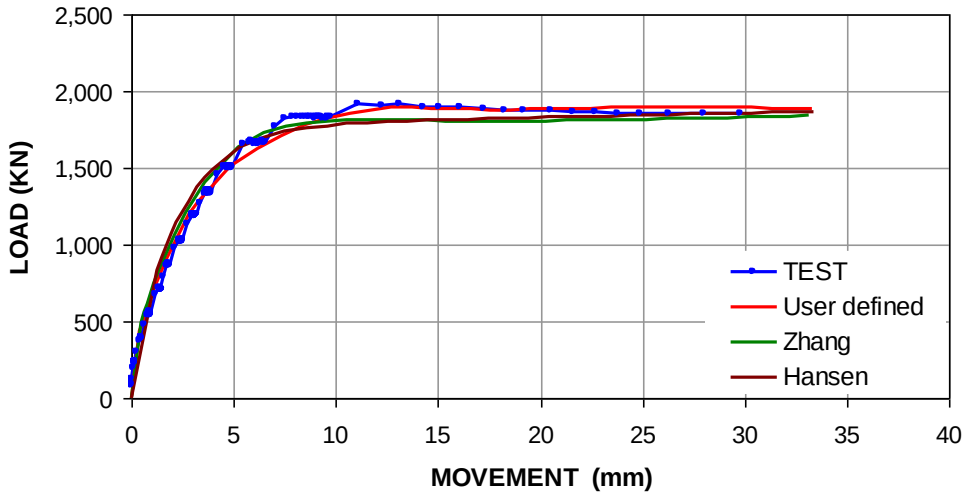
The following show the UniPile graphs for the four shaft shear (t-z) functions included in the example file.



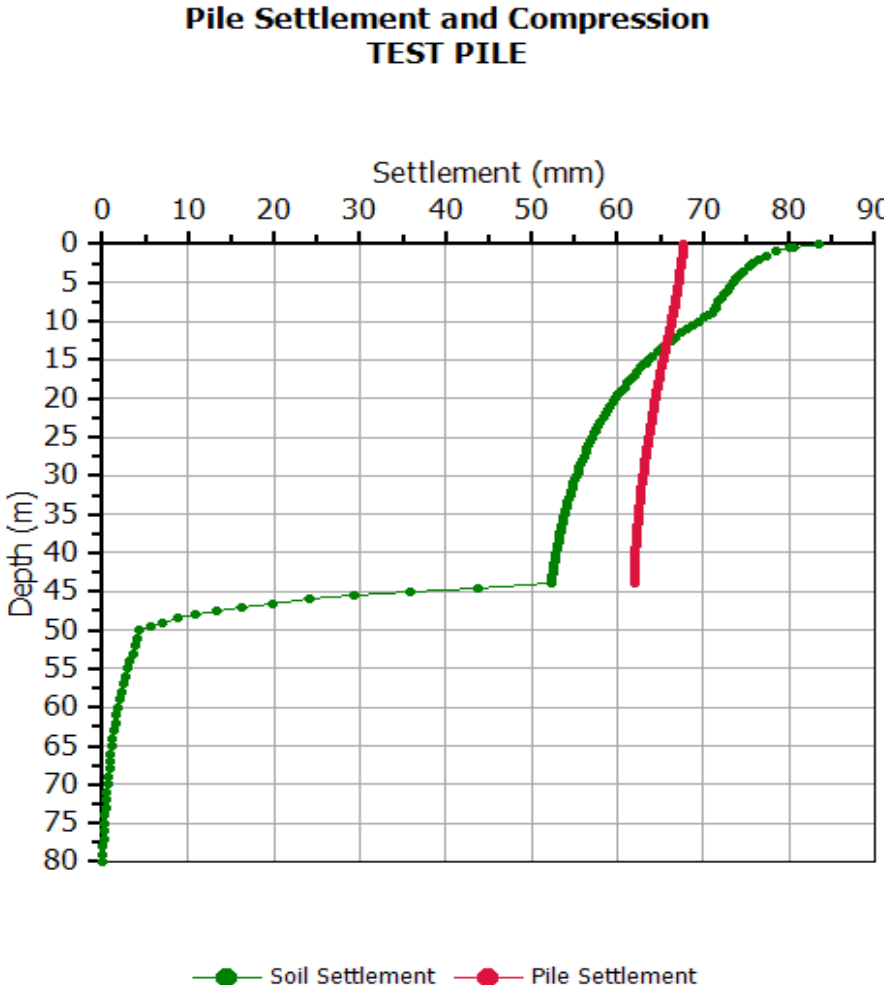
The three t-z functions for the shaft resistance in the clay layer look different because they are plotted to different abscissa scales. However, they are very similar as shown in the below diagram where they have been plotted together and to the same movement axis scales.



The static loading test was simulated in UniPile for the three different clay shear t-z functions and the same function for the sand (shaft and toe). The below diagram shows the simulated static loading test load-movement curves together with the measured load-movement curve. (The individual "Head-down Loading Test Simulations" were exported to text files which were then imported to Excel for the plotting).



The test pile case history applied in Example 2 pertains to a study for a future bridge abutment. The example file includes the size (tentative at this time) of the future pile group, the number of piles within that group, and the width and height of the embankments (two separate fills) leading up to the bridge abutment. UniPile applies the change of effective stress between the "initial" and "final" condition to calculate the total and distribution of soil settlement and the settlement of the piled foundation. The piles supporting the piled foundation are assumed equal to the test pile. (The analysis can easily be adjusted to some other size and length of piles). The settlement of the pile foundation is based on the Unified Method which states that the settlement of the piles is determined from the requirement that, at the neutral plane, the settlement of the piles and the settlement of the soil are equal.



The User is encouraged to change the various inputs and see the resulting changes of the fit between measured and matched data. Before doing so, however, save the example file under a new name to avoid messing up the demo example.

EXAMPLE 3 - STP444

In 1968, Hunter and Davisson presented an important paper on analysis of load transfer of piles in sand. The paper was the first to show measurements of residual loads in full-scale tests, and that such loads will greatly affect the load transfer evaluated from load measurements in a static loading test (as had been postulated by Nordlund 1963). The case history demonstrates that residual load is not restricted to piles in clay, but will develop also for piles in sand. The findings were later confirmed by the case history reported by Gregersen et al. (1973). Indeed, the two cases show that a drag force can also develop for piles in sand. The data for one of the piles in the paper, "Pile #1", have been included in the file "Example 3 - STP444.Unipile5" to enable a re-evaluation of the data in the paper and for demonstrating the software.

The tests were performed in a homogeneous deposit of "medium dense medium to fine sand" with SPT N-indices ranging from 20 through 40 (mean value of 27) and a bulk saturated density of the sand of 124 pcf. (The actual set of N-values is not available). The groundwater table was at a depth of 3 ft (hydrostatic pore pressure distribution can be assumed). Laboratory tests indicated an internal friction angle in the range of 31 degrees through 35 degrees. The friction angle for a steel surface sliding on the sand was determined to 25 degrees.

Static loading tests in push (compression test) followed by pull (tension test) were performed on six piles instrumented with strain gages and/or telltales. The piles were all installed an embedment depth of 53 ft and had a 2-foot stick-up above ground. The detailed test data are not included in the paper, only the total load and the evaluated toe loads (in both push and pull). The following data are excerpted from the paper. The pile diameter is stated to be 12.75 inch. The circumferential area of 3.96 ft^2/ft and the toe area of 3.96 ft^2 indicate a pile diameter to 15.125 inch and a toe area of 13.40 in^2. The values include the areas of guide pipe channels outside the pipe housing the instrumentation.

Pile #	Type	Shaft Area (ft^2/ft)	Toe Area (ft^2)	Installation Method
1	Pipe	3.96	0.98	Driven; Vulcan 140C

The paper does not include the load-movement curves from the static loading tests, only the evaluated ultimate resistances. The following table summarizes the ultimate resistances (pile capacities) and the toe resistances evaluated from the tests.

Pile #	Push Test			Pull Test		Adjusted Push	
	R^{ult} (kips)	R_s (kips)	R_t (kips)	R_s (kips)	R_t (kips)	R_s (kips)	R_t (kips)
1	344	248	96	184	-74	174	170

The table data indicate that the piles were subjected to a negative (-74 kips) toe resistance during the pull test, which, of course, is not possible. (It would mean that there was someone down there holding on and pulling the other way). The negative toe resistance observed is due to residual load induced in the pile caused by the pile installation and the preceding push test. If the 184-kip resistance measured in the pull test is taken as the true shaft resistance, the true toe resistance would be 160 kips (344 - 184).

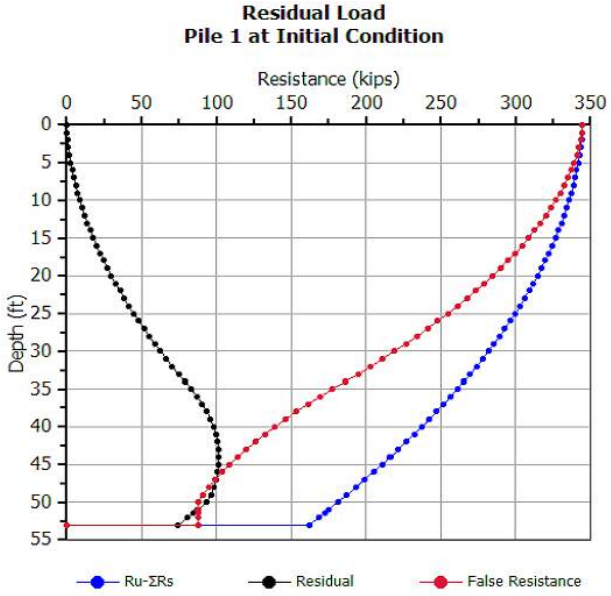
Hunter and Davisson (1969) adjusted the data for the push test by increasing the toe load by a value equal to the 74-kip apparent negative toe load of the pull test and decreasing the shaft resistance correspondingly—linearly to the pile head. The so-adjusted values are shown in the two rightmost columns above.

The paper reports the effective stress parameters in a beta-analysis matched to the data. These data have been compiled in the table below and used as input to the UniPile program together with the soil and pile data as given above. The results of the UniPile computations are included in the table.

Pile #	Input Values		UniPile Analysis		
	N_t (--)	ß (--)	R^{ult} (kips)	R_t (kips)	R_s (kips)
1	53	0.50	377	194	183

The paper concludes that there is a difference in shaft resistance in push and pull as indicated by the different beta-coefficients evaluated from the push and pull tests. However, a review of the data suggests that the beta-coefficient determining the shaft resistance lies in the range of 0.45 through 0.52 for the piles and that the shaft resistance is about the same in push and pull. A "perfect" match to the 344-kip total resistance and the shaft and toe resistances of 184 and 160 kips (165-ksf), respectively, is achieved using a ß-coefficient of 0.47 and a unit toe resistance of 165 ksf.. However, the purpose of this account is not to discuss the merits of details given in the paper, but to use the data to demonstrate the load-transfer analysis. The significance of the paper is the clear demonstration that the influence of residual loads must be included in the evaluation of pile test data.

The amount and distribution of residual load in a pile can be calculated by the same effective stress approach as used for matching the test data. A computation of Pile 1 with a residual load portion of 46 % of the toe resistance results in a computed residual toe resistance of 74 kips, which would mean that the "negative toe resistance" is close to what the authors reported in the paper. The corresponding "false shaft and toe resistances" are 258 and 88 kips, respectively. The diagram presents the push-test load transfer curves for the True Resistance, the Residual load, and the False Resistance distribution curves as determined using the UniPile software.



EXAMPLE 4 - TRB1169

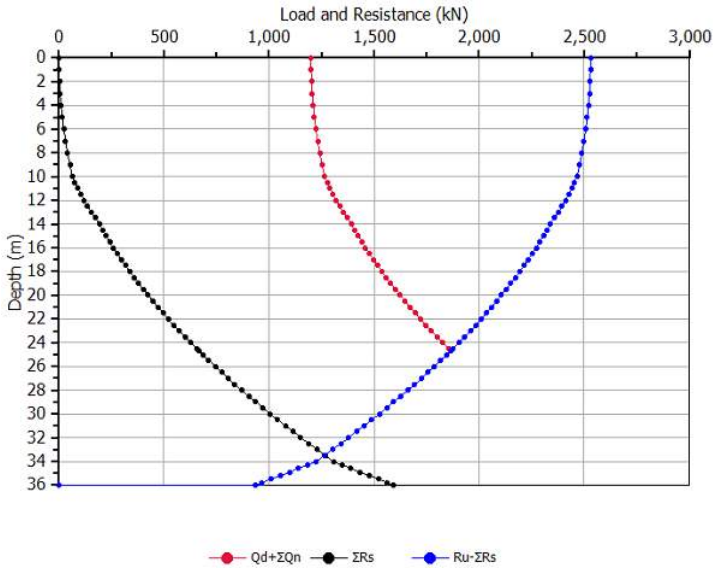
The unified method for design of piled foundations was developed by B.H. Fellenius in the early 1980s (first published by Fellenius 1984). It combines capacity, drag force, settlement, and downdrag in an interactive-unified-approach. Fellenius (1988) advanced the approach and included a design example which was the first example of how to pursue a numerical analysis.

The design case presents a pile group consisting of 10 piles to be installed at the site, where the soil profile consisted of 10 m of soft or firm clay on a 4 m thick layer of sand. Below the sand lies a 20 m thick layer of slightly overconsolidated silty clay deposited on dense ablation till. The groundwater table is at the ground surface and the pore pressure is hydrostatically distributed. Some time after installing the piles and erecting the structure, a 2 m thick fill, causing a stress of 15 kPa is to be placed across the site. The soil parameters are listed in the below table and the data have been input to a UniPile file called "Example 4 - TRB1169.Unipile5".

Depth Range (m)	Type	Density kg/m^3	ß (--)	m (--)	m_r (--)	j (--)	Δσ' (kPa)
0 - 10	Clay	1,550	0.25	20*	200	0	20*
10 - 14	Sand	2,000	0.45	250	--	0.5	--
14 - 34	Clay	1,740	0.35	80*	400*	0	120
> 34	Till	2,100	0.60	400	--	0.5	--

(*The four underlined values were mistyped in the original paper)

The 10 piles consist of 300 mm diameter pipe piles driven closed-toe to 36 m depth below the ground surface. The piles will be concrete-filled after driving and the intended allowable working load per pile is 1,400 kN of which 1,200 kN is dead load and 200 kN is live load. The maximum structurally allowable axial load at the neutral plane is 2,100 kN. The pile cap footprint is 3.5 m by 5.0 m, i.e., the area is 17.5 m^2 and the total 12,000-kN dead load corresponds to a 686-kN stress.

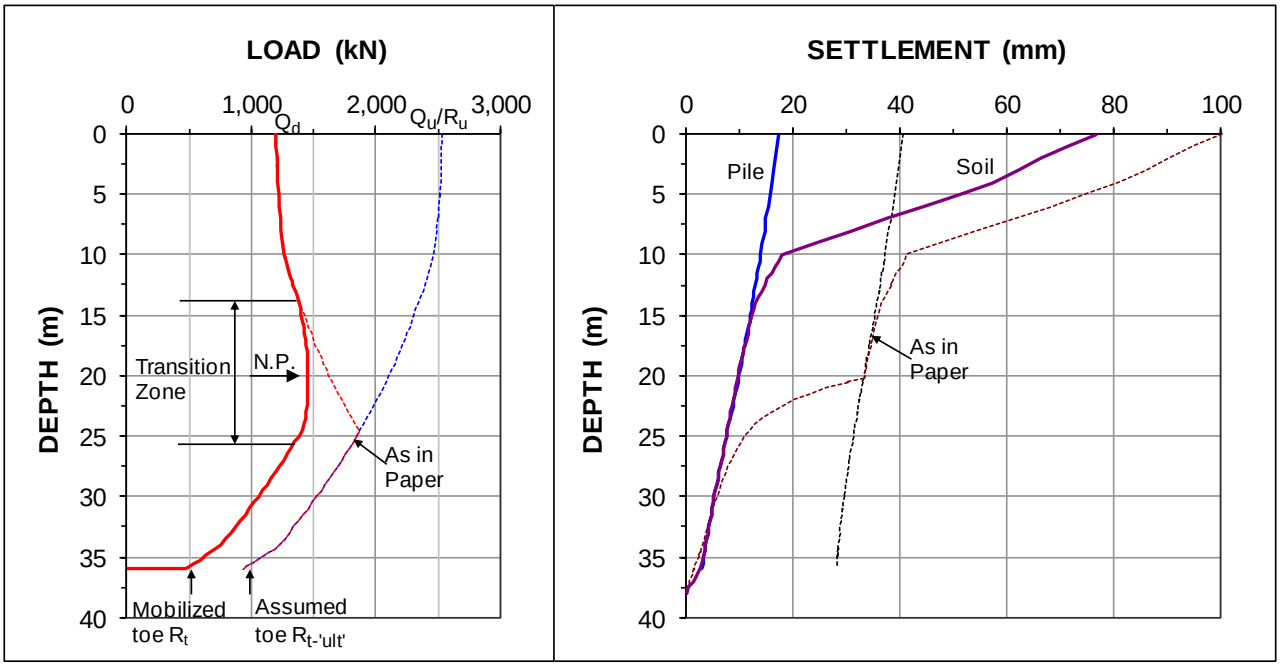


The calculated values of capacity and resistance distribution are shown in the above figure. The curves differ slightly from the results given in the paper. This is because the original calculations were made before the advent of the personal computer which means that they include shortcuts and simplifications necessary for hand calculations. However, the differences are no larger than the original plot and the plot looks identical to that in the paper. Similarly to the diagram in the paper, the figure disregards the effect of a transition zone.

At the time when the paper was written, the fact that the pile toe load-movement relation is an essential part of the pile-soil response as well as of the location of the neutral plane was not fully understood. Moreover, neither was the necessity of considering the stiffness effect of a group piles on the compressibility of the soil between the neutral plane and the pile toe level. The settlement distribution presented in the paper was therefore larger than what an analysis with the insight of today would show.

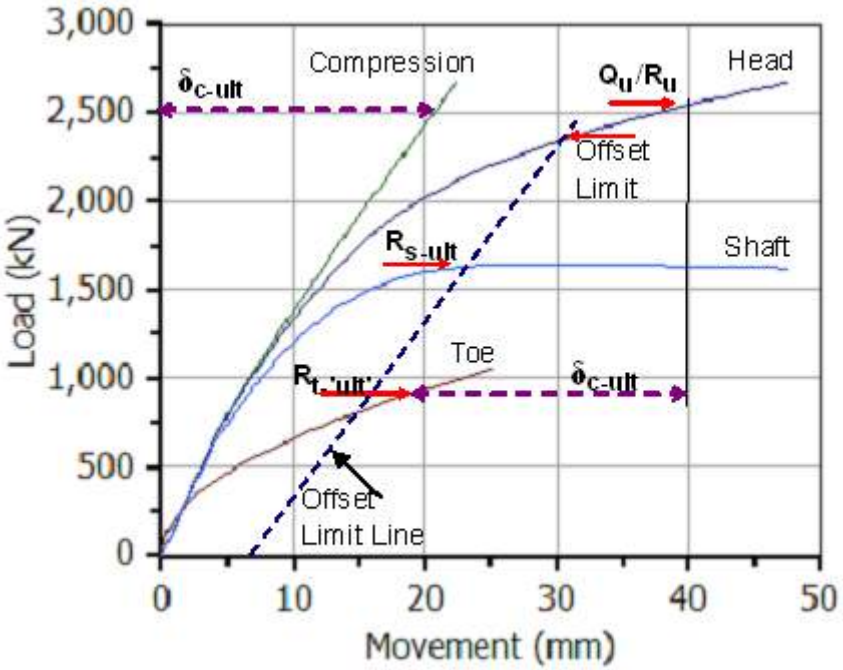
The below figure (left part) shows the load distribution from the dead load (Q_d) assuming a 7 m high transition zone above the neutral plane and that only half the toe resistance ($R_{t\text{-}'ult'}$) is mobilized. The latter is the distribution when the ultimate resistance of the pile (the capacity) is mobilized as in a loading test. The small relative movement between the pile shaft and the soil is what suggests using a long transition zone. The load distribution presented in the paper is also shown.

The right part shows the settlement calculation for an equivalent raft placed at the pile toe with the load at the Equivalent Raft widened at 5V:1(H) to the pile toe (as recommended in the "Red Book").



Adding the stiffening effect of the piles to the soil compressibility and considering that the downdrag enforced pile toe penetration into the till is small would have caused the resistance mobilized by the pile toe to be much smaller than that assumed for the capacity calculation. As indicated in the above figure, this has resulted in a significantly smaller drag force and pile settlement than shown in the paper.

In the early 1980s, there was no easy way to simulate the load-movement results of a static loading test. However, with UniPile it is very simple. By selecting suitable t-z and q-z functions, UniPile applies the soil parameters and pile properties and calculates the loading test results illustrated in the below figure. Each soil layer was assumed to be governed by a different t-z function (they are included in the Example 4 file). As no actual test data are available to fit to the results, the only effort made was to select the movement values, particularly for the q-z function in the till so that the calculated capacity, Q_u/R_u, matches the ultimate shaft resistance, $R_{s\text{-}ult}$, as well as the calculated toe resistance, $R_{t\text{-}'ult'}$, mobilized in the test.



The curves have been supplemented with the "Offset Limit Line", which indicates an Offset Limit of ≈2,400 kN; slightly lower than the 2,530-kN capacity resulting from the input soil parameters summed up for each pile element. It would neither be time-consuming nor difficult to re-select the t-z and q-z curves to establish a "perfect" agreement between the capacity calculation and the Offset Limit capacity (as a first step, it would require removing the strain-softening for the shaft resistance). However, as there are no actual test data to fit to, such effort would only be for cosmetic reasons. Besides, there is no requirement that the summed up resistance of the individual elements should actually be the capacity perceived from the pile-head load-movement curve of a static loading test by some chosen definition. For example, the UniPile calculation shows that, at a 30-mm toe movement, the then applied load at the pile head in the test would be 2,760 kN, which value can be considered as an additional definition of pile capacity.

(The foregoing two graphs are produced by exporting the UniPile result tables to text files, clipping and pasting the data to an Excel file that then is used to produce the graph and add the labels, or combine results of different tables).

EXAMPLE 5 - TAPER PILE

The file Example 5 - Taper.UniPile5 contains the data for a square, step-tapered pile with a 200-mm toe diameter and a 1,000-mm pile head diameter installed to 9-m depth in sand. The groundwater table lies at the ground surface and no fill and excavation are included. The purpose of the example is to show the "toe effect" in the calculation of capacity. For a step-tapered pile, the "donut- shaped" protrusion at each step obviously adds resistance at each step along the pile shaft. Where the soil data includes a toe bearing coefficient, UniPile, when requested (Pile data/Pile input), will compute an extra "toe resistance" for each such "extra toe".

To see the effect of a smooth taper, go to File/Import UniSoft Files/My Documents and select the file called "Smooth Taper data.xmlu" (we assume that you installed the UniPile demo files in this folder). The import will replace the step-taper pile data with the smooth taper pile data. For many reasons, the taper will have a beneficial effect on the shaft resistance, offsetting the decreasing shaft circumferential area. As mentioned in the Background text, the "Red Book", one can account for this by more or less arbitrarily boost the ß-coefficient. Or, one can consider a "toe effect" also for this pile. It is a bit more difficult to conceive of a "toe effect" for a smooth-tapered pile. Think of it as a projection downward of the wider portion of the pile. A length of pile above a particular point in the pile will project as a ring around the pile, much the same as the donut-shaped step for the step-tapered pile. UniPile includes the option of computing a "toe resistance" for the projection between the calculation depths (determined by the "steps" assigned in the soil data table. The User can compare the two piles as to the similarities and differences and the significance of the "toe effect". Why not try building a pile that is both smooth tapered and step-tapered?

EXAMPLE 6 - SCOUR

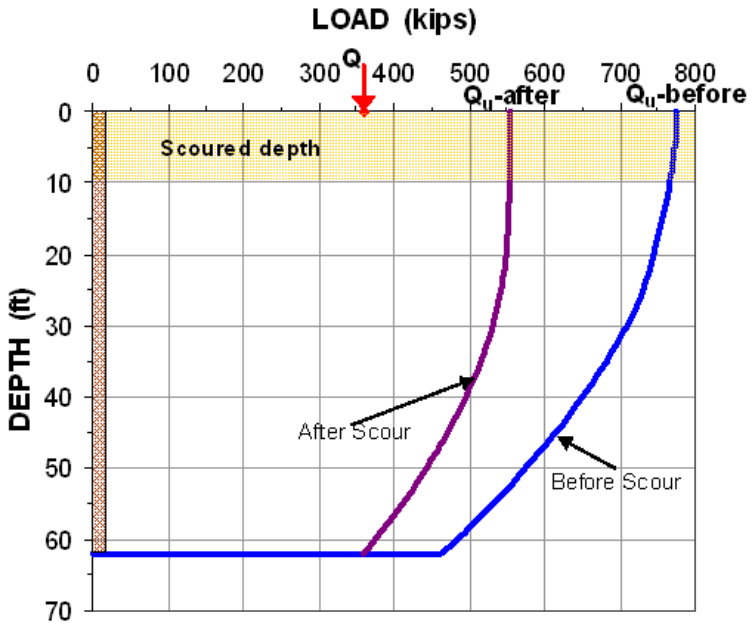
UniSoft has received several questions from Users on how to apply the programs to actual problems. The following is a problem brought to us by an engineer at a DOT office.

A bridge will be founded on piers supported on groups of 18 inch (450 mm) pipe piles driven closed-toe through an upper 26 ft (8 m) thick layer of silty sand and 36 ft (11 m) into a thick deposit of compact sand. The groundwater table lies 6.5 ft (2 m) below the ground surface (bottom of a dry river). A static loading test has established the pile capacity to be 775 kips (3,450 KN), which corresponds to beta-coefficients of 0.35 and 0.50 in the silty sand and compact sand, respectively, and a toe bearing capacity coefficient of 60. The design load was 360 kips (3,200 KN), which indicates a factor of safety of 2.15-slightly more than adequate.

The static test had been performed during the dry season and a review was triggered when the question was raised whether the capacity would change during the wet season, when the groundwater table was expected to rise above the ground surface. And, what would the effect be of scour? In the review, it was discovered that the upper 10 ft (3 m) of the soil could be lost to scour over significant area around the piles, termed "general scour". However, in the design of the bridge, losing the shaft resistance in the upper 10 ft had been thought to be inconsequential to the pile capacity.

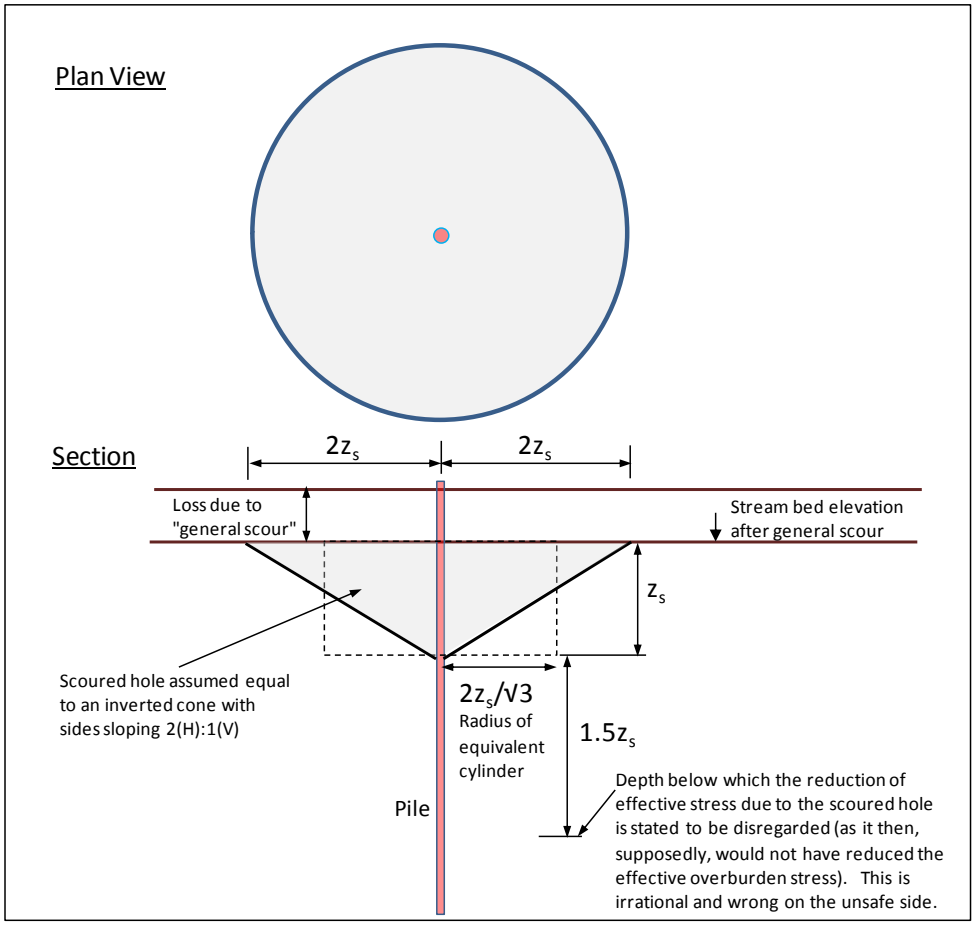
The file Example Scour.UniPile5 contains the data. A static analysis will answer the question about the effect on the pile capacity after scour. The distribution of pore water pressure is hydrostatic at the site and, in the Spring, when the groundwater table will rise to the ground surface (and go above), the effective overburden stress reduces. As a consequence of the change of the groundwater table, both pile shaft resistance and toe resistance reduce correspondingly and the new total resistance is 680 kips (3,020 KN). That is, the factor of safety is no longer 2.11, but the somewhat smaller value of 1.89-not quite adequate.

When the effect of scour is considered, the situation worsens. The scour can be estimated to remove the soil over a wide area around the piers, which will further reduce the effective overburden stress. The capacity now becomes 550 kips (2,450 KN) and the factor of safety is only 1.54. The diagram below shows the resistance distribution curves for the condition of the static loading tests and for when the full effect of scour has occurred.



Missing the consequence of reduced effective stress is not that uncommon. Fortunately, in the subject scour case, the consequence was no so traumatic. Of course, the review results created some excitement. And had the site conditions been different, for example, had there been an intermediate layer of settling soil, there would have been cause for some real concern. As it were, the toe resistance was considered not to be reduced significantly by the reduction of effective stress (try it by changing the toe input to a 265 ksf unit toe resistance and use this for both initial and final condition) and a recalculation of the dead load showed it to be about 330 kips instead of 360 kips. In this case, therefore, it was decided to not carry out any remedial measures, but to keep a watchful eye on the scour conditions during the wet seasons to come. Well, a happy ending, but perhaps the solution was more political than technical.

Moreover, when scour develops around piles, nearest the pile and to some distance out from the pile, a conical hole develops that also removes effective overburden stress. The FHWA recommends that the base of the cone be assumed to be four times the depth (the "height" of the inverted cone) as illustrated in the below graph.. It is easy to include this in a UniPile calculation. The hole is simply input as an excavation with the geometry of the scoured out volume, say, as a series of circular slices.


Plan View
Section
2z_s
2z_s
Loss due to "general scour"
Stream bed elevation after general scour
z_s
Scoured hole assumed equal to an inverted cone with sides sloping 2(H):1(V)
2z_s/√3
Radius of equivalent cylinder
1.5z_s
Pile
Depth below which the reduction of effective stress due to the scoured hole is stated to be disregarded (as it then, supposedly, would not have reduced the effective overburden stress). This is irrational and wrong on the unsafe side.

EXAMPLE 7 - TABLES 1.6 and 7.3

The Red Book by B.H. Fellenius serves as background text to the UniSoft software. Chapter 1 contains a soil profile illustrating calculation of distribution of total and effective stresses and pore pressure compiled in Table 1.6. The same profile is used in Chapter 7 to illustrate calculation of load and resistance distribution compiled in Table 7.3. Both tables are produced in UniPile. The Example 7 - Tables 1_6 and 7_3.Unipile5 includes the soil profile and soil parameters behind the tables.

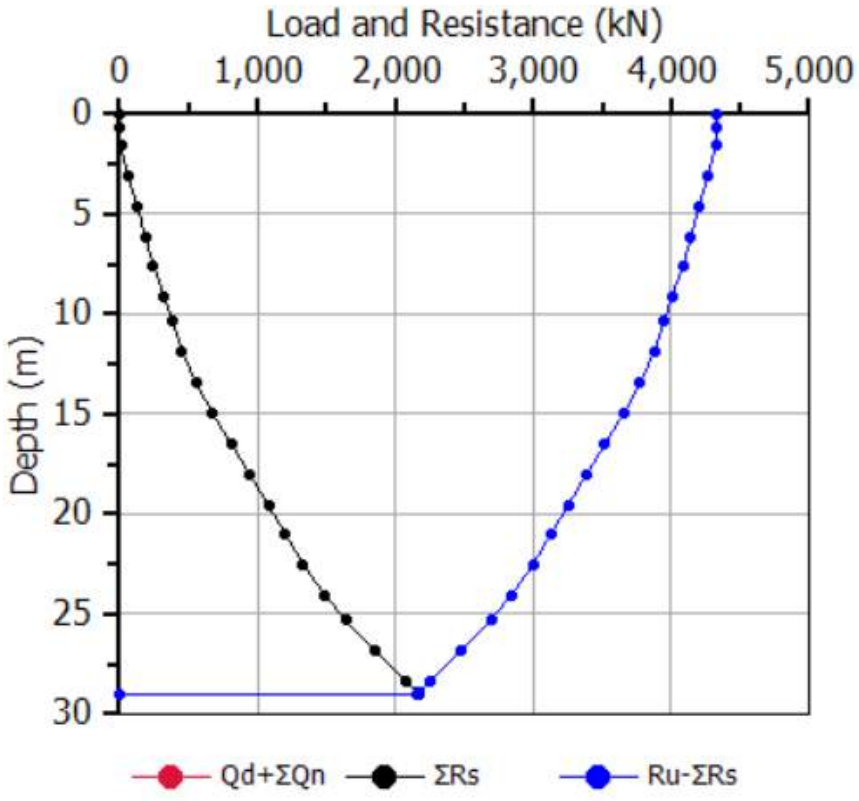
Example 8 - SPT Example

The Standard Penetration Test, SPT, is the most common method for obtaining soil samples and an estimate of the soil relative density, the N-index. Some will apply the N-indices to an estimate of pile shaft and toe resistances according to the formulae proposed by Meyerhof (1976), Decourt (1988; 1995), and O'Neill and Reese (1999), quoted in the Red Book (Fellenius 2014). The file called Example 8-SPT presents the details of a square 12-inch diameter, 95 feet long pile driven into a sandy silt changing to silty sand, where SPT N-indices have been obtained at 5-foot spacing.

The file is prepared with the pile and soil layer information and the SPT data have been imported (*File\Import SPT and CPT/CPTU data \SPT N-indices.txt*). In importing the records, note that the computer needs to be told the number of headings lines, the units of measure, and which column contains the N-indices. Importing SPT data will override the existing records, if any.

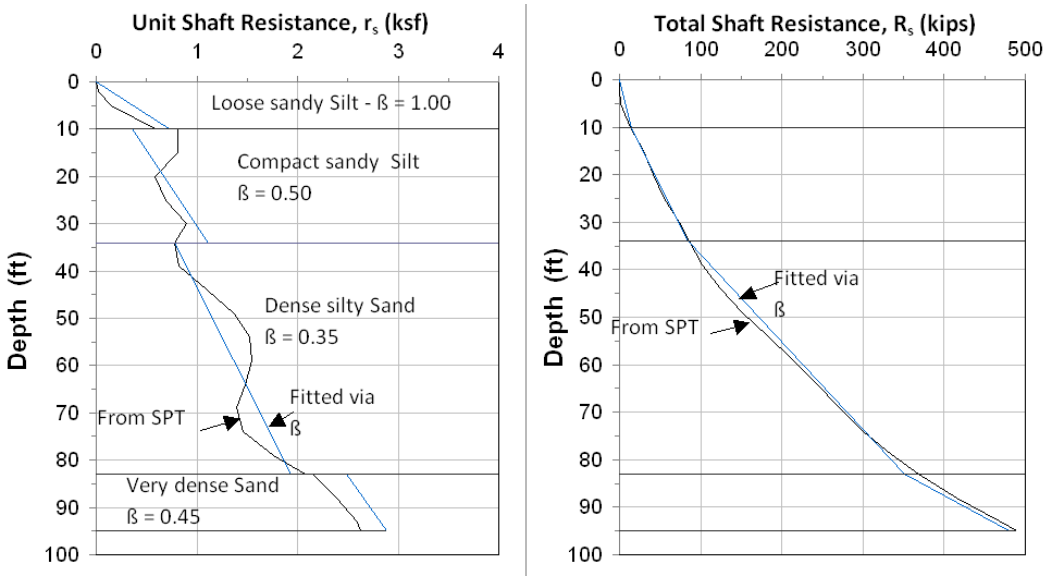
Borehole information has established the soil profile and the depth to groundwater table (2 ft), and the information has been input to the file in terms of soil type, layer thickness, soil density, and soil void ratio. (For a calculation limited to the capacity from the SPT N-indices, only one layer (depth and density) is a necessary input. Input of compressibility, pile group configuration, and t-z and q-z functions is not needed.

Before performing the analysis, select General Input\Settings\Pile Resistance\Method\Meyerhof (SPT). Performing the analysis, provides all pertinent results, such as the pile capacity and load and resistance distributions just like a "static" analysis would.



UniPile produces a "Pile Resistance Table ("R_u") listing the equivalent beta-coefficients of the calculations from each SPT-N method as selected. The far right column labeled "Equivalent Beta" lists the beta-coefficients calculated as averages between the N-index depths. It is easy to establish the average beta-coefficient for each soil layer. The coefficients are 1.0, 0.5, 0.35, and 0.45, respectively, approximated to the nearest 0.05 precision.

The following two graphs show a comparison between the unit shaft resistances calculated from the Meyerhof SPT method and that from the input of the back-calculated layer averages (left graph), as well as the two resulting distributions of total shaft resistance (right graph).



The beta coefficients, ß=1.00 and ß=0.50, in the two upper soil layers may seem a bit excessive. Adjusting them to the more reasonable values of about 0.20 or 0.30, only reduces the total shaft resistance by about 50 kips. More important, the 500-kip and 500 ksf total toe resistance and unit toe resistance, respectively, would seem to be about twice a reasonable value. It should be remembered that Dr. Meyerhof developed his method from back calculations of results from static loading tests on expanded base piles ("Franki" piles). With the lower beta-coefficients and toe resistance, the calculated pile capacity becomes about 300 kips, which sounds like a reasonable value.

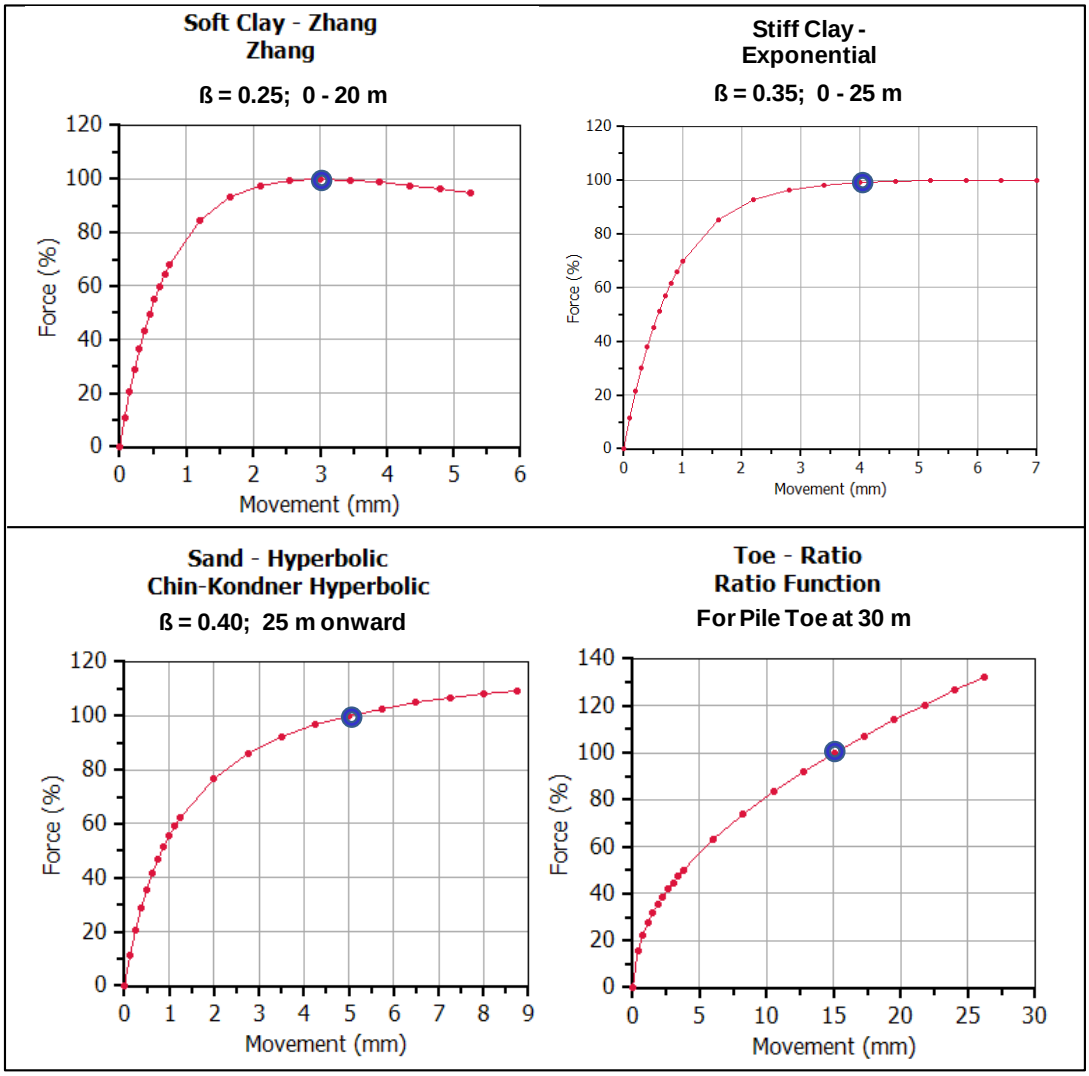
Note that the SPT method does not consider changes to the effective stress from change of the groundwater table depth or from excavations and fills occurring after the boring was made (for that matter, it is far from certain that the SPT would have reacted to any such change at the site).

The User is encouraged to try out the Decourt and O'Neill-Reese STP methods. Select method at "Settings".

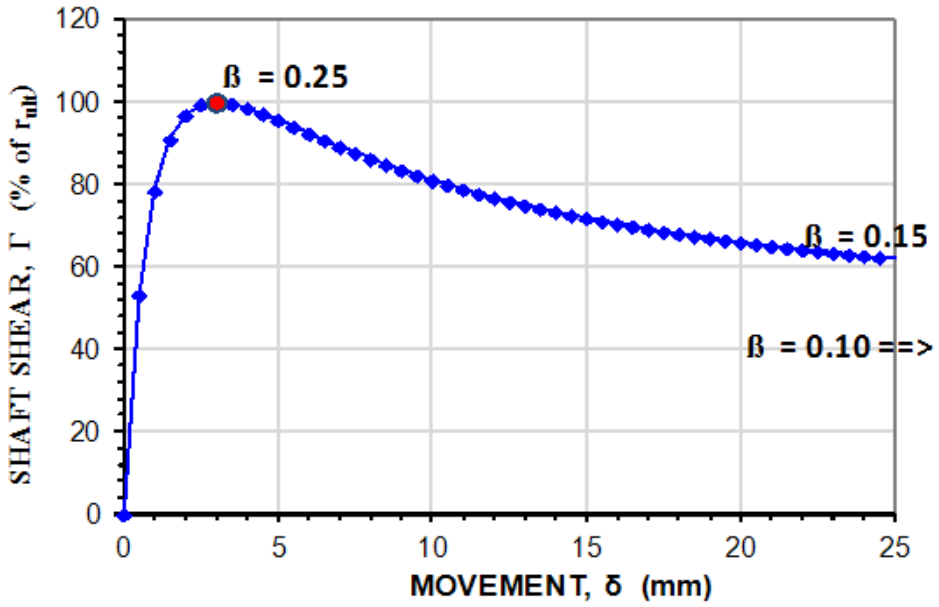
Example 9 - Advanced Analysis

As demonstrated in Examples 2 and 3, the results of an instrumented static loading test can easily be back-calculated to determine the basic soil parameters corresponding to the pile response. Example 9 contains a 300-mm diameter test pile installed to 30 m depth through 20 m of soft clay, and 5 m of stiff clay into sand. It is assumed that the pile has a gage level at each 5 m depth. (Had the instrumentation been placed at odd depths, output at these depths could be arranged by entering the depths at "General Input\Depth Points").

The ultimate shaft resistance in each soil layer is represented by a beta-coefficient (analysis will be by effective stress method). The toe resistance is input as a unit value (5,000 kPa) for a 15-mm toe movement (as found in the static loading test). Each soil layer has a different shaft resistance vs. movement response, t-z function, as indicated in the below figure. As seen, the shaft response in the upper 20 m thick layer of soft clay is strain softening, in the stiff clay between 20 and 25 m depth it is essentially elastic-plastic represented by exponential function, and in the sand below 25 m depth it is strain-hardening per hyperbolic function. The toe resistance is assumed to follow a ratio function.



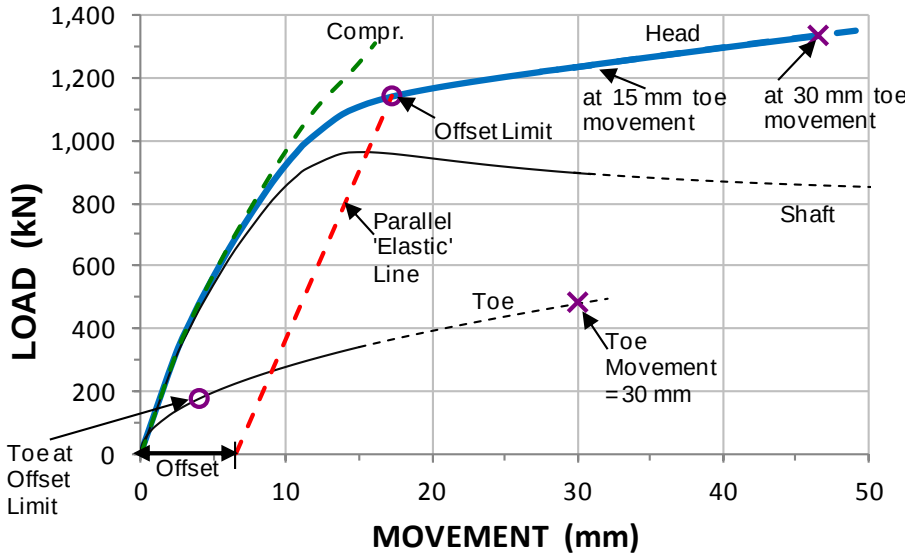
The t-z and q-z function graphs can be extended in the help file "Cribsheet.xls" available for downloading from UnisoftLtd.com or from Fellenius.net. For example, the below graph shows the strain-softening Zhang function over the first 25 mm of movement. The shear resistance of hundred percent (ß = 0.25) occurring at 3 mm movement reduces to about 60 % (ß = 0.15) at 25 mm movement. At infinite movement, the shear resistance has reduced to 40 % (ß = 0.10).



UniPile calculation output consists of capacity—total and separated on shaft and toe: 1,400, 1,050, and 350 kN, respectively, and many other aspects depending on input. A key result is the load movement curves of the test:

- the pile head and pile toe versus pile head and toe movements, respectively
- the pile shaft resistance and pile compression (shortening) versus pile head movement
- the pile head load versus pile toe movement (represents the measurement of a telltale placed at the pile toe)

The following figure shows the loading test results after exporting the result table as a text file and importing it to an Excel sheet for plotting and adding of text labels.



The results have been supplemented with the 1,140 kN offset limit load (Davisson 1972). The round purple circle on the toe curve indicates the toe movement (5 mm) for when the applied load was equal to the offset limit load. The purple **X** marker shows the total load and applied load for the assigned 30 mm toe movement. The toe resistance at 15-mm movement was 350 kN, but at 30-mm toe movement, the toe load is 500 kN. Moreover, at 30-mm toe movement, the load applied to the pile head is 1,470 kN, not 1,400 kN. The reason is that the capacity calculation uses the soil parameter input for ultimate resistance, whereas the loading test simulation includes the effect of strain softening and strain hardening—as governed by the t-z and q-z curves.

It is important to realize that the load distribution results are those for the ultimate resistance values calculated using the input soil parameters, i.e., for shaft resistance, the beta-coefficients, and/or unit shaft resistance values and, for toe resistance, the N_t-coefficient or the assigned "ultimate" unit toe resistance. The input of maximum toe movement (General Input\Settings\Loading Test Simulation\Max. Toe Mvmnt) has no influence on the load distribution results. Its purpose is to limit the movement axis in the representation of the results of a static loading test. Most of the time, the calculated load distribution is representative for the soil response at end of the static loading test, when the shaft response usually can be assumed to be in a plastic response state. However has demonstrated in the example, when the post-peak soil response is clearly not plastic, the calculated capacity and that indicated by the loading test simulation will not agree. This may create difficulties when calculating the soil response from actual test results.

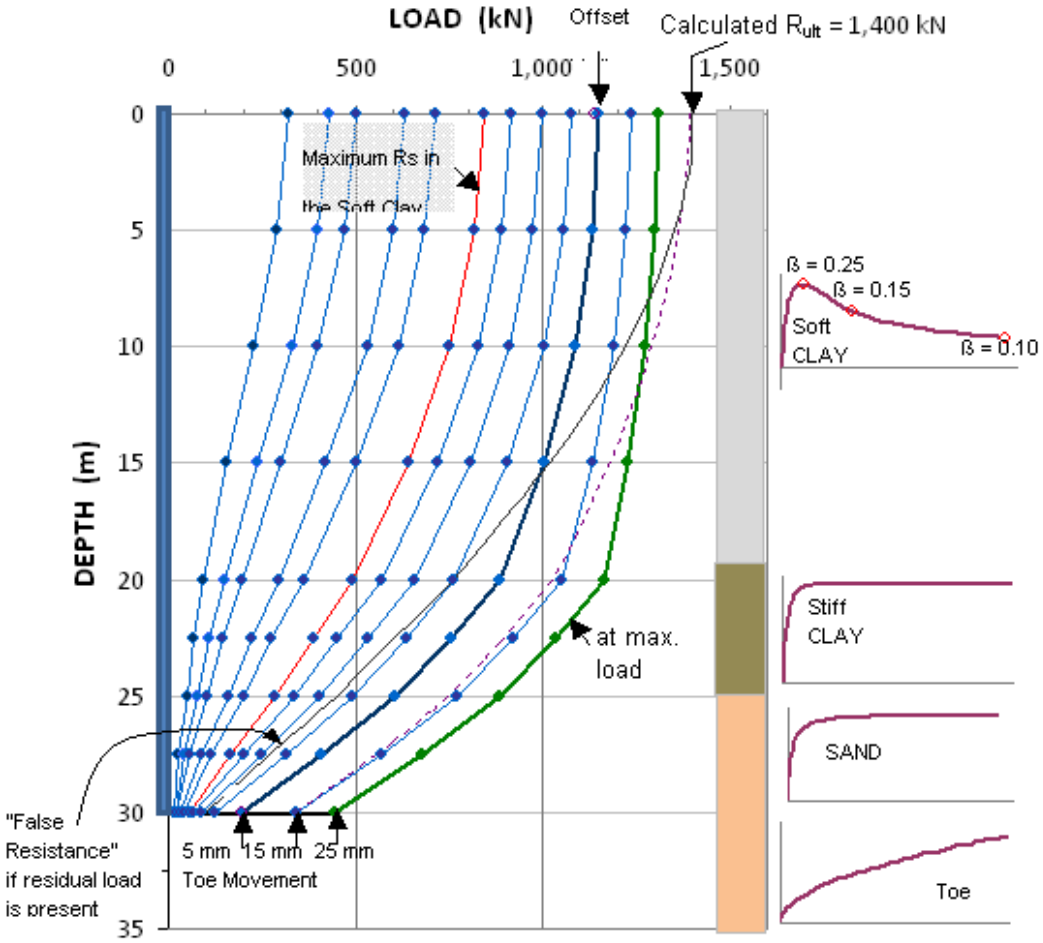
If a static loading test is performed on an instrumented pile, as, indeed, all test piles should be, then, load values will be obtained at each gage level. Moreover, the results of the instrumented test will consist of the load distribution for different pile head loads, which is not directly provided in the UniPile output. However such output can easily be obtained, as demonstrated in the following advanced analysis of Example 9.

The loading test simulation provides the pile head loads for an array of pile toe load and movements., i.e., the uppermost and lowermost values in a graph of load distribution along the pile. The load values at the first gage level, 5.0 m depth, are simply obtained by indicating zero shaft resistance above 5 m and assign the pile stiffness above 5 m as infinite, i.e., 1,000,0000 kPa, and repeating the loading test simulation. Doing the same for the next and following gage level depths, provides the array of loads at all gage levels. The loads and movements at the pile toe are common for all the simulations. Each calculation is simply exported as a text file

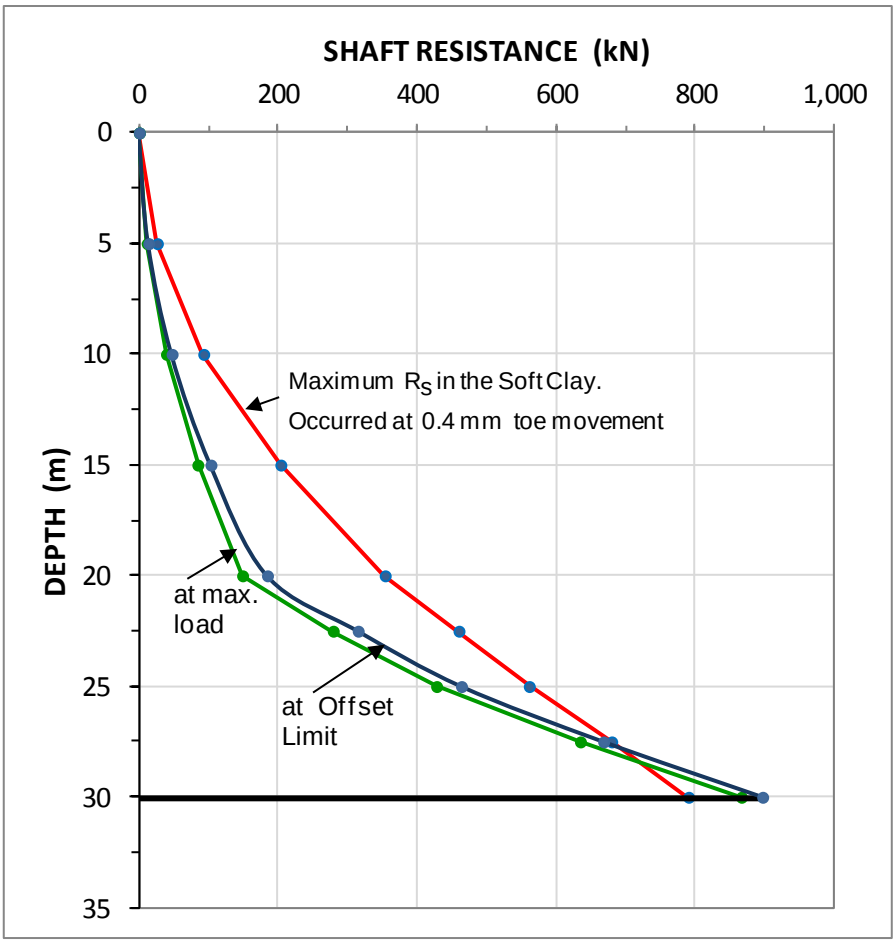
that is clipped and pasted into an Excel sheet; in this case, resulting in six tables of loading test results. It is easy to build a load distribution table containing the loads at the pile head and pile toe at each gage level for the array of pile toe movements, which can be plotted as shown in the below figure.

The load distributions obtained from the simulations can now be used to fit observed distributions and load movement curves between gage levels to calibrate a specific soil profile to actual test results. Such calibration results are useful when applying results of a static loading test at the site to other piles at the site considering changes in pile length and soil profile.

Obviously, if only the load distribution at the maximum applied load is desired, then, the input beta coefficient in the soft clay should be the post peak value at a toe movement considered suitable; the Red Book suggests 30 mm. This toe movement and corresponding maximum load could would then define the capacity of the pile to use in a design.



The following figure shows the shaft resistance distribution plotted for toe movements when the total shaft assistance in the soft clay was at its maximum, which occurred when the toe movement was a mere 0.4 mm. The figure also shows the shaft resistance at the offset limit load and at the maximum test load when the toe movements were 5 and 25 mm, respectively. It's obvious that, once the offset limit had been reached, the further reduction of shaft resistance was small.



Example 10 - The Unified Design procedure

A two-storey warehouse will be constructed with a 50 m by 150 m footprint. The building outside walls, the upper floor, and the roof will be supported on columns exerting a 3,200-kN dead load (800 kN/pile) and placed about 15 m apart. No appreciable live load is anticipated. There will be no inside walls in the ground floor. Each column foundation will include four, 300-mm diameter, driven precast prestress concrete piles placed in a square configuration at a c/c of 1.5 m. Pile testing at the site has established the pile length to be 20 m. The ground floor will be placed level with the ground surface and consists of asphaltic concrete. The ground-floor loading will amount to 50 kPa and is considered to be a uniformly distributed sustained load.

The structural engineer indicates that a 50-mm differential settlement between the columns will be acceptable for the structure.

A site investigation involving boreholes with split-spoon sampling, CPTU soundings, Shelby tube sampling, and laboratory studies has been performed. Presenting the detailed results of the investigation is beyond the purpose of this example and here only a summary will be provided. It must be remembered, however, that this is a crucial part of the foundation design. Often, a site investigation is planned according to expectation of shallow foundations. The investigation is therefore geared to establishing the conditions of the upper soil layers. Then, when the results show the necessity of a piled foundation, the site investigation is only too often not extended to provide the required information for the deep foundation design. Happily, this is not the case of the example.

The investigation has shown that the soil profile consists of 2.5 m of loose to compact sand on 12.5 m of compressible, slightly preconsolidated, marine clay deposited on dense to very dense sand at a depth of 15 m. The dense sand is at least 15 m thick and is underlain by a veneer of very dense glacial till on bedrock. The groundwater table is located at a 3.0-m depth and the pore pressure distribution is hydrostatic.

- The upper loose to compact sand layer has a total density of 2,000 kg/m3 and a void ratio of 0.67.
- The marine clay layer has a total density of 1,600 kg/m3 and a void ratio of 1.76.
- The lower dense sand layer has a total density of 2,200 kg/m3 and a void ratio of 0.39.

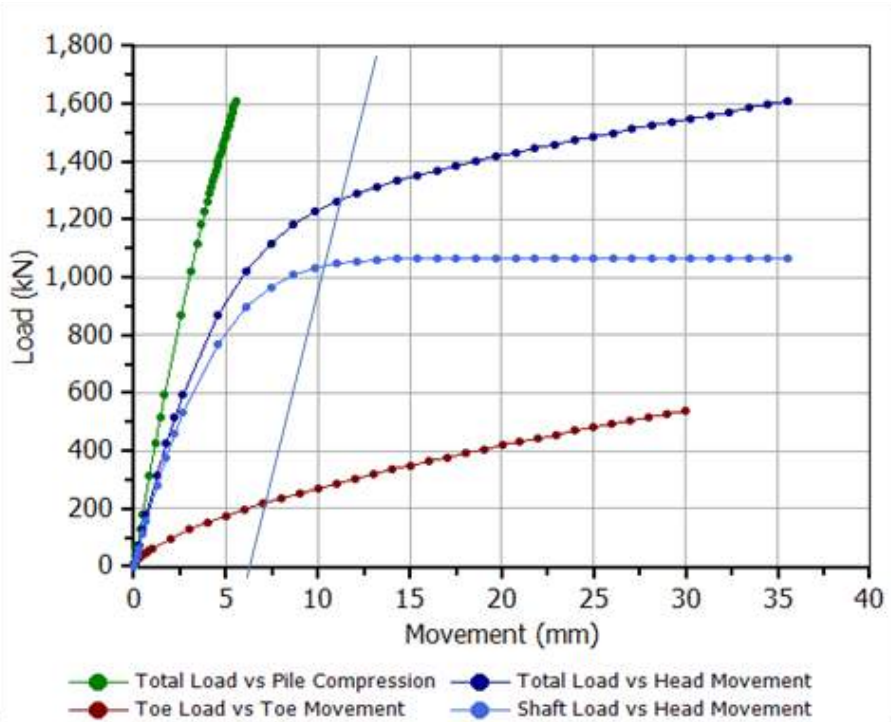
The piled foundation design will be performed according to the unified design method. The procedure involves two main steps. The first is verifying that the loads from the supported structure—dead plus live; sustained plus transient—are adequately safe considering the pile capacity. The second is verifying that the settlement of the piled foundation will be adequately smaller than the maximum value the structure will accept (there will always be settlement) before the structure is inconvenienced or, in the extreme, damaged. This step also verifies that the maximum load in the pile (occurring in the long-term at the neutral plane) is safe considering the axial strength of the pile.

The two-step procedure will be based on normally occurring conditions of load and soil profile. The analysis is then developed into a more complex case by introducing "complications" often encountered in practice.

The compressibilities (Young moduli) of the upper and lower sand layers are estimated to be 40 MPa (j=1; m=400) and 100 MPa (j=1; m=1,000), respectively, applicable to a linear response to load ('elastic' condition). Oedometer tests on the marine clay have established that C_c = 0.63 and C_{cr} = 0.063, which, when coupled with the void ratio values, e_0, they show that the compressibility of the clay in terms of Janbu modulus numbers is m = 10 and m_r = 100, or, in terms of MIT compression ratio coefficients: CR = 0.23 and RR = 0.023. The preconsolidation margin in the clay is 40 kPa (corresponds to OCR = 1.8 at the upper clay boundary and to OCR = 1.4 at the lower clay boundary).

The analysis of the pile response to load will be performed in an effective stress analysis which requires the input of the appropriate ß-coefficients. We assume that a static loading test has been performed at the site on a pile similar, but not necessarily identical, in size, length, and construction. The following ß coefficients and unit toe resistance were used to produce the loading test curves of this "virtual test": for the shaft resistance in the upper sand, the clay, and the lower sand, they are 0.40, 0.25, and 0.60, respectively, and the unit toe resistance is 6 MPa (540 kN) at a 30 mm toe movement. In an actual test, the coefficients and unit toe resistance would have been established in a back-analysis of the test results.

Moreover, the t-z and q-z functions for the pile response have also been established: For both sand layers, the shaft resistance response can be modeled by the Exponential Function with the exponent equal to 0.5, which essentially describes an elastic-plastic response for the pile element with the shift from 'elastic' to plastic response occurring at a movement between 5 mm for 90 % of ultimate to 10 mm for 100 %. Thus, the analysis benefits from a well-defined ultimate shaft resistance. No such ultimate resistance exists for a pile toe, of course. The pile toe response of the example pile is assumed to follow a Ratio function with an Exponent of 0.63. This exponent means that a doubling of the toe force results in a trebling of the toe movement, i.e., the mentioned 6-MPa stress mobilized at 30-mm movement corresponds to a 3 MPa unit toe resistance at 10 mm movement. The below figure shows the results of the static loading test. Note that the results do not include any influence of residual load. Moreover, the shaft resistance shows neither strain-softening nor strain-hardening—a rather unusual load response.



Load-movement curves established in a virtual static loading test on the 20 m long, 12-inch square concrete pile at initial condition

Step 1 — Pile Capacity

In choosing a unit shaft resistance ß-coefficient, it is usually understood that, in an effective stress analysis, the unit shaft resistance determined by the coefficient is the ultimate resistance, i.e., the shaft capacity (as, for that matter, would be the case also for a total stress analysis with direct input of unit shaft resistance). Although ultimate toe resistance does not exist, the 'toe capacity' is here assumed—defined—to be the toe load that generates a 30-mm toe movement, as stated above.

When the mentioned parameters are used in a simple spread-sheet calculation, the distribution with depth of effective stress along the pile is easily obtained. Then, by multiplying the effective stress at each depth with the ß-coefficient, adjusting for pile circumferential area, and accumulating the values along the pile, the pile capacity is quickly determined. The condition immediately after the warehouse has been constructed is the "initial condition", which is the condition before any loads, fills, and other effects pertaining to the "final condition" are placed at the site. Thus, before any floor loads have been placed in the building, the total pile capacity is 1,607 kN (R_{shaft} = 1,067 kN; R_{toe} = 540 kN), which means that the factor of safety is 2.01. If, as in the assumed case, the capacity is established by a static loading test, this factor of safety is normally considered adequate.

Note, however, that there are many methods for determining the pile capacity from the pile-head load-movement curve measured in a static loading test. With regard to the results shown in Figure 1, capacity can be interpreted to range from a low of about 1,200 kN through the maximum load applied: 1,607 kN, (capacity must never be extrapolated from a loading test). That is, the capacity interpreted from the test may not agree with the capacity summed up from the pile elements and, vice versa, the average shaft resistance back-calculated from a capacity determined from the pile-head load-movement curve of a static loading test will not necessarily be that determined from the particular pile elements.

For the piled foundation design, it is not important that the capacity will increase with time after the consolidation of the clay from the floor load is completed—the design must consider the case of the least capacity. However, the consolidation will result in a settlement of the soil, primarily of the compressible clay layer, which will impose downdrag (settlement). It is very important that the settlement be assessed in the design (See Step 2).

Step 2 — Load Transfer, Settlement, and Downdrag

When the warehouse is constructed, the transfer of the 800-kN/pile dead load will be associated with some downward movement of the pile as well as 'elastic' shortening. As the ultimate shaft resistance (1,067 kN) is larger than the dead load, it will not be fully mobilized along the lower portion of the pile. However, some load will reach the pile toe and cause a small pile toe movement. It is realistic to assume that the lowest pile element will penetrate a few millimetre, maybe 5 mm for the example case, into the soil. The pile shortening due to the 800-kN pile-head load will be about 3 mm. Some load-transfer movement will be caused by the load from the 4-pile group compressing the soil layers below the pile toe. The effect of the load transfer above the pile toe is covered by the shaft resistance shear-movement relation. Vertical stress distribution along the pile shaft can be assumed not to cause measurable settlement near the piles because of the reinforcing (stiffening) contribution of the piles. The calculation of the settlement of the soil below the pile toe level can be made assuming that the load acts on an equivalent footing placed at the pile toe. The compression of the soils below the pile group toe level will cause an about 3 mm additional settlement[1)]. The total pile settlement immediately after the construction of the warehouse will thus amount to about 10 mm. For most structures, these immediate "settlements" can normally be considered inconsequential and be disregarded.

[1]) Change, temporarily, the equivalent raft area to 9.5 x 9.5 m (pile group input; see the Red Book) to reflect the load-spreading along the pile shaft as 20% of the pile length and run the analysis. The results table for settlement will display the soil settlement at the pile toe depth due to the load on the pile group plus sustained floor load.

When the floor load is placed, consolidation plus a small contribution due to compression of the sand layers will result in a long-term settlement of the ground amounting to about 150 mm at the ground surface and about 25 mm at the pile toe level[2)]. The resulting downdrag on a piled foundation located in the center of the structure footprint causes a 26-mm calculated piled foundation settlement for a neutral plane at 12.6 m depth. However, this location presupposes that the total pile toe penetration is 30 mm, but the calculation shows that the net penetration due to the downdrag is only about 20 mm. Considering the initial about 5 mm toe penetration, the calculation needs to be adjusted to a smaller toe force (5,500 kPa), which results in a raising the neutral plane to 12.0 m depth and shows a 32 mm pile settlement due downdrag. The settlement values are about the same. However, at other sites and for other conditions, not matching the toe resistance to the toe penetration may result in significant error in the estimated downdrag magnitude. Moreover, calculations using different unit toe resistance values will show that the results are very sensitive to the input values. This supports the general advice that piles in settling soils, where downdrag is expected, should aim for the location of the neutral plane to be below the settling soil layer, that is, the design may have to aim for a larger toe resistance and larger capacity than otherwise considered necessary.

A column foundation located near the outer wall or at the corner will settle appreciably less than one in the center. The long-term differential settlement will be about half the total, say, about 20 mm[3)].

The maximum axial load will be about 1,300 kN, which is well within the acceptable considering the pile axial strength.

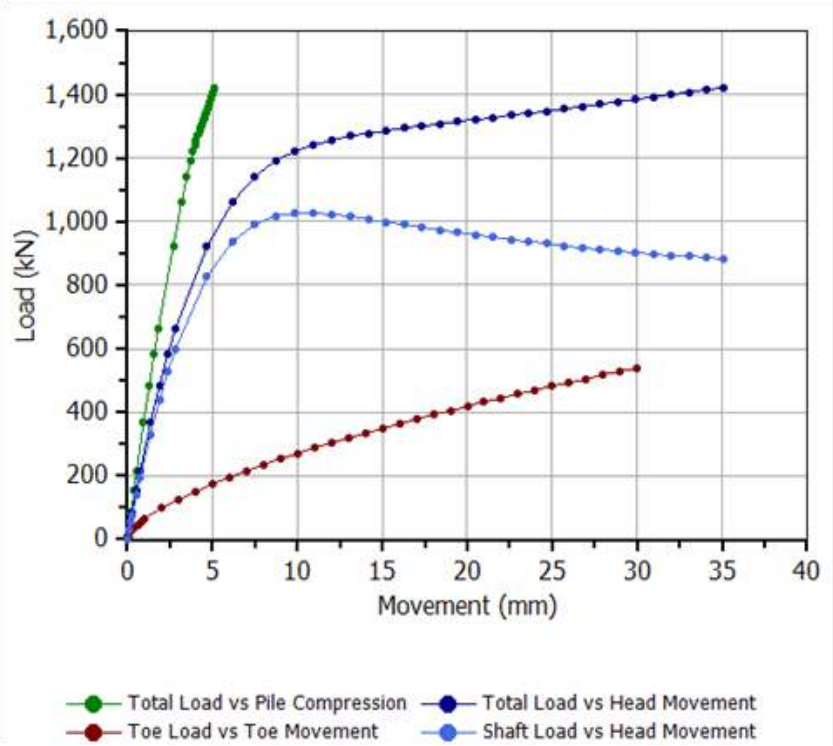
It would seem that the warehouse foundation is adequate both with regard to capacity and settlement.

Realistic Shaft Resistance t-z Function

The case is a "textbook" case, meaning that it is rather simpler than most real life cases. The most obvious simplification is the assumption of elastic-plastic shaft resistance in the clay layer. Shaft resistance in clay is usually strain-hardening in firm to stiff clay. In soft clay, as in the current case, it would be strain-softening. The t-z function representative for the case would therefore normally be the Hansen or the Zhang functions. The below figure shows the results of a simulated loading test for the t-z function in the clay layer input as a Zhang function with the "a-coefficient" equal to 0.0125 ("Shaft in clay -- strain-softening"), which indicates that if the ultimate shaft shear is mobilized at a 5-mm movement and, then, at a 30-mm movement the shaft shear is reduced to about 75 % of the ultimate. The effect of this is that the maximum load (at 30 mm pile toe movement) has reduced by 200 kN, to 1,422 kN from 1,607 kN. The capacities determined by other methods have been reduced similarly. For example, the Offset Limit reduces from about 1,350 kN to about 1,300 kN. Note however, that the assumed ultimate shaft resistance (per the input ß-coefficient) calculated by UniPile is still 1,607 kN.

[2)] Return the input of the equivalent raft area to 6.5 x 6.5 m (pile group input reflecting the load-spreading from the neutral plane to the pile toe 20% of the pile length below at about 12.5 m depth; see the Red Book), adjust, temporarily, the toe resistance input to 5,500 kPa (to consider the pile toe load for the actual pile toe penetration) and run the analysis. The results table for settlement will display the soil settlement at the pile toe depth, as well as the pile settlement.

[3)] The settlement for a pile located along the outer wall or at a corner of the footing can be calculated by indicating new coordinates for the pile and the pile group (Pile Data input), e.g., x =25 m and y = 75 m for the middle of a long side and x = 0.75 m and y = 0.75 m for a corner pile in the pile cap. This calculation will also demonstrate the sensitivity of the calculations to the input preconsolidation margin, which in a real case might trigger a reassessment of the margin.



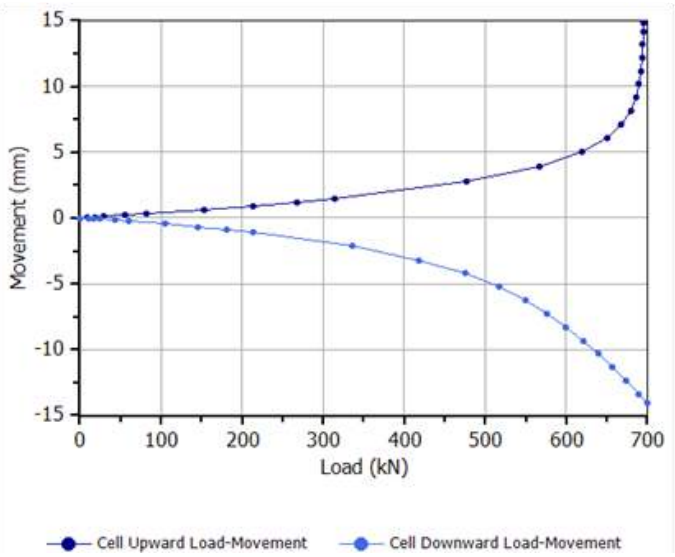
Load-movement curves for a simulated static loading test with strain-softening shaft resistance

Bidirectional test

Most static loading tests are uninstrumented and the only records taken are those at the pile head: the pile-head load-movement. Such tests (called "head-down tests") provide very little useful information. Of course, one can construe a pile capacity from the curve by some definition or other. But what that capacity actually represents is highly ambiguous and of little use for assessing the pile foundation's response to load. It would, however, satisfy a bureaucrat's wish for having a value to which to apply a factor of safety or a resistance factor. Much of the uncertainty can be removed by placing strain-gage instrumentation at a few depths in the pile. However, this significantly increases the costs of the test and strain-gage records require evaluation as to reliability and accuracy of the records, as well as resolving confusion about what the measured strains actually represent. The best way to obtain useful records of the pile response in a test is to perform a bidirectional test, that is placing a hydraulic jack, or jacks, at a suitable depth and perform the test by letting the jack(s) simultaneously push the upper portion of the pile upward and the lower portion downward.

The below figure shows the virtual results of a bidirectional test for the same pile, load, and soil conditions as the head-down test shown earlier. The bidirectional cell is placed at 17 m depth (to represent a desired emphasis of the response of the lower pile length in the lower dense sand). The curves are shown in the manner of a conventional test report, i.e., the "Settings" input for the "Shaft Buoyant Weight" is "Include". The graph is cut-off at equal upward and downward loads, which is the case for an actual bidirectional test. However, UniPile calculates the upward and downward results independently and continues until the calculated pile toe movement reaches the specified toe movement, which can result in different upward and downward movements. That the upward and downward movements for the maximum load are equal (almost) here is a coincidence.

Usually, the bidirectional cell is placed at the presumed "balance level" so as to ensure that both the upward and downward load-movement responses are obtained. When planning a test, it is a good rule to "err" on the side of the upward response being the smaller, because, then, the test will establish the downward response, which is the most important part of a test. If more information on the response of the upward length is desired, one can always carry out a simple tension test. No equally simple and low-cost enhancement test exists for the downward response.



Load-movement curves established in a simulated bidirectional loading test with the cell placed at 17 m depth

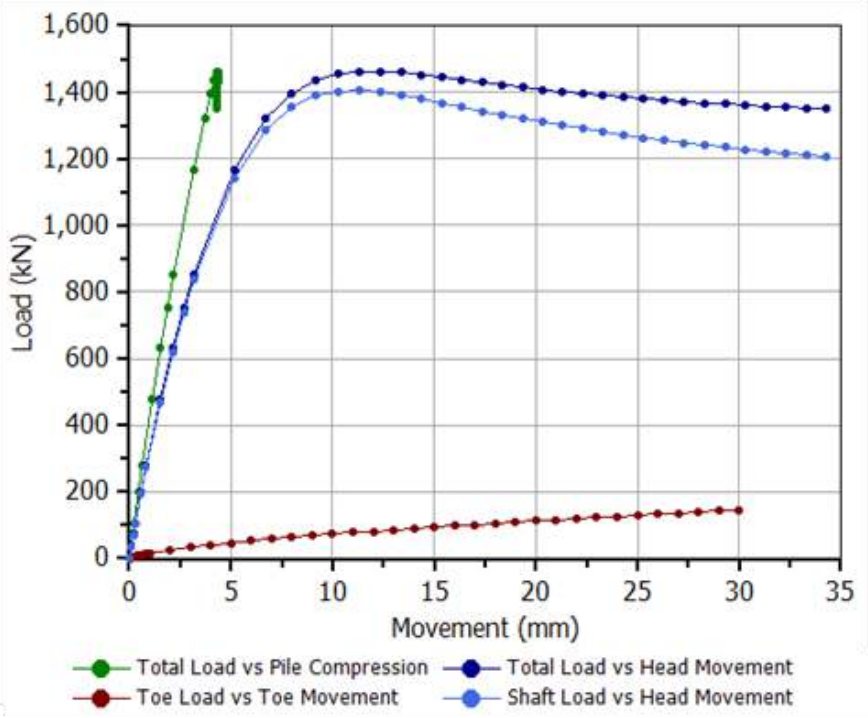
Residual load

Normally, at the start of a static loading test, load already exists in the pile. This load is called "Residual Load". It is almost always present in a driven pile after the driving. It may also occur in a bored pile, because residual load can develop during the time elapsed from the construction (installation, driving, casting) to the testing. Residual load is caused by the soil having moved down relative to the pile, or the pile moved up (as in a swelling soil). These movements can be very small and yet develop considerable residual load. The relative movement is resisted by negative direction shear forces in the upper portion of the pile and by positive direction shear forces along the lower portion. The mechanism is similar to the build-up of a drag force.

The residual load is difficult to measure directly. It may affect significantly, and often to a hard-to-determine degree, the load distribution in a test pile, when measured, for example, by strain gages at selected depths. Less realized is that the presence of residual load will also affect the pile-head load-movement curve. For example, if the subject warehouse pile would be affected by residual load along the upper sand and the clay amounting to, say, about 400 kN, which would have to be resisted by a residual load in the dense sand of equal amount, then, a static loading test would result in the load-movement curves shown in Figure 4. A capacity interpreted from the pile-head load-movement curve in Figure 4 would be about 200 kN larger than that interpreted from Figure 1.

When not certain whether or not the test pile is affected by residual load, which capacity value should one rely on? And, if the pile would have been strain-gage instrumented to separate shaft and toe resistance, which shaft and toe resistance distributions would be believed, those of the first figure or the below figure?

The bidirectional test has the advantage that the load measured by the cell is the true load in the pile. This is why a bidirectional test on a strain-gage instrumented pile often shows a discrepancy between the cell load and the strain-gage load near the cell level. The cell load is the correct values and the load difference can be used to assess the residual load in an instrumented pile.



Load-movement curves established in a simulated test on a pile with residual load

The example is taken from the real world and modified from records of a warehouse constructed in the 1960s near Milwaukee, WI. Starting in the mid-1980s, the City constructed a sewage facility that required extensive underground construction and rock tunneling. As a consequence, the phreatic height of the groundwater in the lower sand layer reduced considerably, say, by about 5 m at the example site[4)]. This lowering of the pore pressures in the ground has resulted in a regional settlement and downdrag for many foundations. For the subject example, this can easily be quantified by simply changing the final pore pressure distribution to a 7-m head as opposed to the original 12-m head at the lower boundary of the clay layer. The clay will show a downward pore pressure gradient. The calculations for this condition show that the settlement of the piled foundations will increase. The simultaneous effect of increasing the pile capacity is irrelevant to the case (assuming that the loads from the structure are unchanged).

The main effect of the lowering of the groundwater table will be on the settlement of the clay layer, which will increase from about 120 mm to about 300+ mm. The settlement of the lower sand layer will increase by about 4 mm. The calculated additional downdrag on the piles will be about 10 mm, after including the fact that the toe resistance will increase due to the increased pile toe penetration, which will result in a lowering of the neutral plane. The drag force is of no consequence as the piles are not long.

[4)] Change the Final Pore Pressure/Profile Type to Non Hydrostatic (already in the file) and run the analysis to model the effect of the groundwater table lowering.

The settlement of the floor will not be even and it will be necessary to adjust the height by adding additional asphalt concrete. This will introduce about 5 to 10 kPa additional floor loads, which will cause increased settlement and downdrag.

It is quite possible that over the life of a building, the area around it will be raised by placing fill. This fill will renew the consolidation settlement and cause additional downdrag. It is also quite possible that the use of the warehouse will change to include an increased floor load. The original design should consider all implications and produce a sufficiently conservative foundation design[5)].

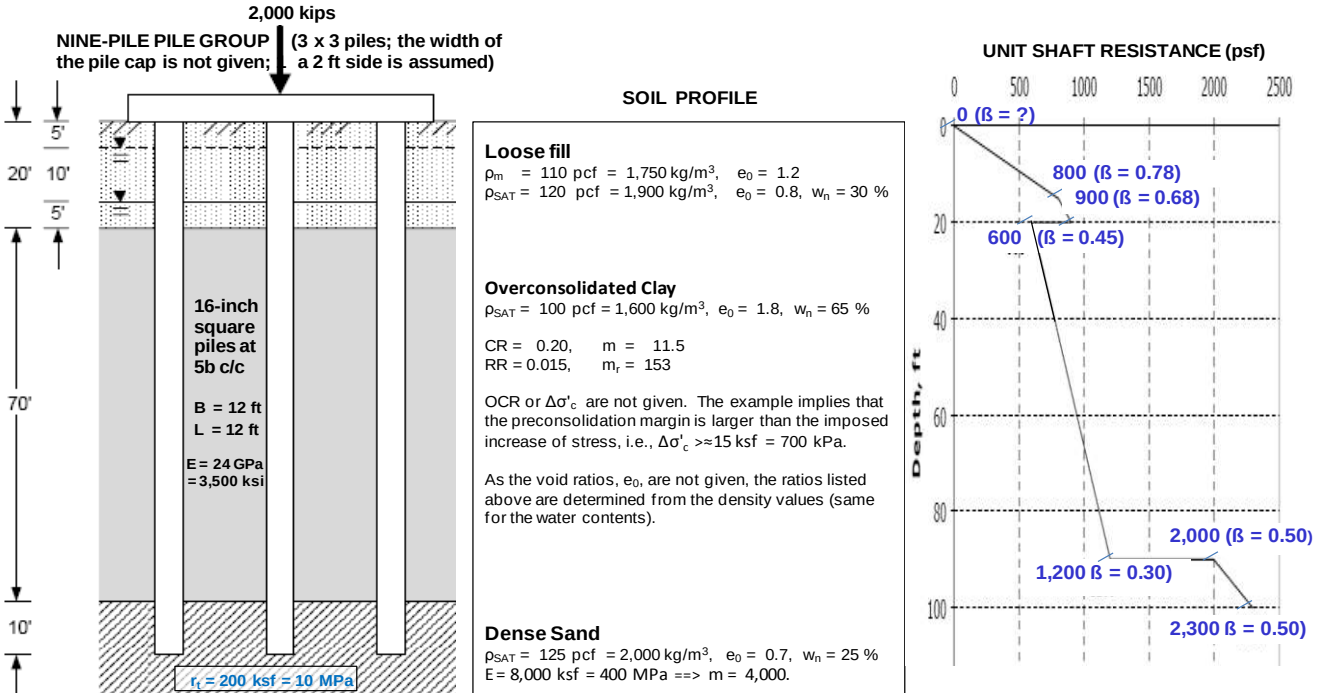
Furthermore, the building might be close to an excavation, a river bank, a dock, or other feature affecting the distribution of effective stress under the warehouse to a larger or smaller extent. In the future, a new building may be constructed adjacent to one side of the first building. All such features are easy to incorporate into an analysis and there is no reason for omitting them.

[5)] The file includes a load option for increasing floor load and for placing fill around the warehouse. Note, no fill will be placed inside the building. It is necessary to adjust the floor load to reflect this. If no new floor load is placed, then, input a negative stress equal to the fill stress as the "New Floor Load to account for the fact that the warehouse is a "hole" in the fill.

Example 11 - The US Corps of Engineers approach

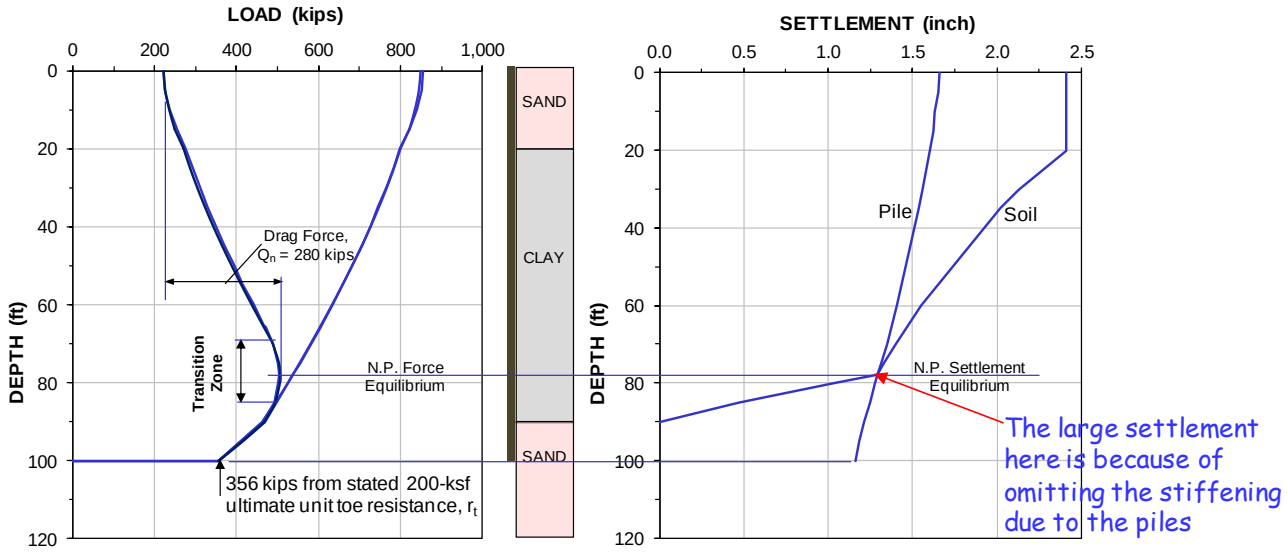
The Unified method is now a recommended method to apply to piled foundation design in many standards and codes, e.g., the Canadian Bridge Design Code, the FHWA Driven Piles Manual, and the US Corps of Engineers Design Guidelines (USCOE-HSDRRSDG, Chapter 3, Geotechnical). Example 11 comprises the Unified Method per the approach recommended by the US Corps of Engineers. The USCOE approach is presented in a 2009 Report CGPR #56 published by Virginia Tech, Center for Geotechnical Practice and Research "Downdrag and Drag Load on Piles" written by M. Greenfield and G. Filz. The report details the Corp's approach.

The basics of the example case as presented in the Virg. Tech report are summarized in the following figure. The report applied total stress values. The beta-coefficients have been derived in a UniPile analysis fitting the results of the effective stress calculations to those of the total stress calculations.


2,000 kips
NINE-PILE PILE GROUP (3 x 3 piles; the width of the pile cap is not given; a 2 ft side is assumed)
5'
20'
10'
5'
70'
10'
16-inch square piles at 5b c/c
B = 12 ft
L = 12 ft
E = 24 GPa = 3,500 ksi
r_t = 200 ksf = 10 MPa
SOIL PROFILE
Loose fill
ρ_m = 110 pcf = 1,750 kg/m³, e_0 = 1.2
ρ_{SAT} = 120 pcf = 1,900 kg/m³, e_0 = 0.8, w_n = 30 %
Overconsolidated Clay
ρ_{SAT} = 100 pcf = 1,600 kg/m³, e_0 = 1.8, w_n = 65 %
CR = 0.20, m = 11.5
RR = 0.015, m_r = 153
OCR or $\Delta\sigma'_c$ are not given. The example implies that the preconsolidation margin is larger than the imposed increase of stress, i.e., $\Delta\sigma'_c$ >≈15 ksf = 700 kPa.
As the void ratios, e_0, are not given, the ratios listed above are determined from the density values (same for the water contents).
Dense Sand
ρ_{SAT} = 125 pcf = 2,000 kg/m³, e_0 = 0.7, w_n = 25 %
E = 8,000 ksf = 400 MPa ==> m = 4,000.
UNIT SHAFT RESISTANCE (psf)
0
500
1000
1500
2000
2500
Depth, ft
0
20
40
60
80
100
0 (ß = ?)
800 (ß = 0.78)
900 (ß = 0.68)
600 (ß = 0.45)
2,000 (ß = 0.50)
1,200 ß = 0.30)
2,300 ß = 0.50)

The example is a bit construed. A water content of 65 % (from the density given as 100 pcf) and a compressibility of CC = 0.20 (i.e., m = 11.5) coupled with a prestress margin of ≈15 ksf (i.e., 2,000 kips on a 12 x 12 ft pile cap) is hardly realistic. The large preconsolidation margin was probably imposed on the example to arrive at a moderate settlement value than otherwise would have resulted for the equivalent raft (placed up in a soft, then, essentially normally consolidated clay at the Neutral Plane, N.P.),

The report used the information to calculate the pile capacity, load distribution, and settlement of the piled foundation. The settlement calculations for the equivalent raft placed at the N.P. disregarded the stiffening effect of the piles. The stress distribution below the raft is by 2(v):1(h), the stiffening effect of the piles is omitted, and the sand compressibility is not included (a 12-ft long transition zone is applied). The results were presented in the following graphs, which are replotted from the data in the report.

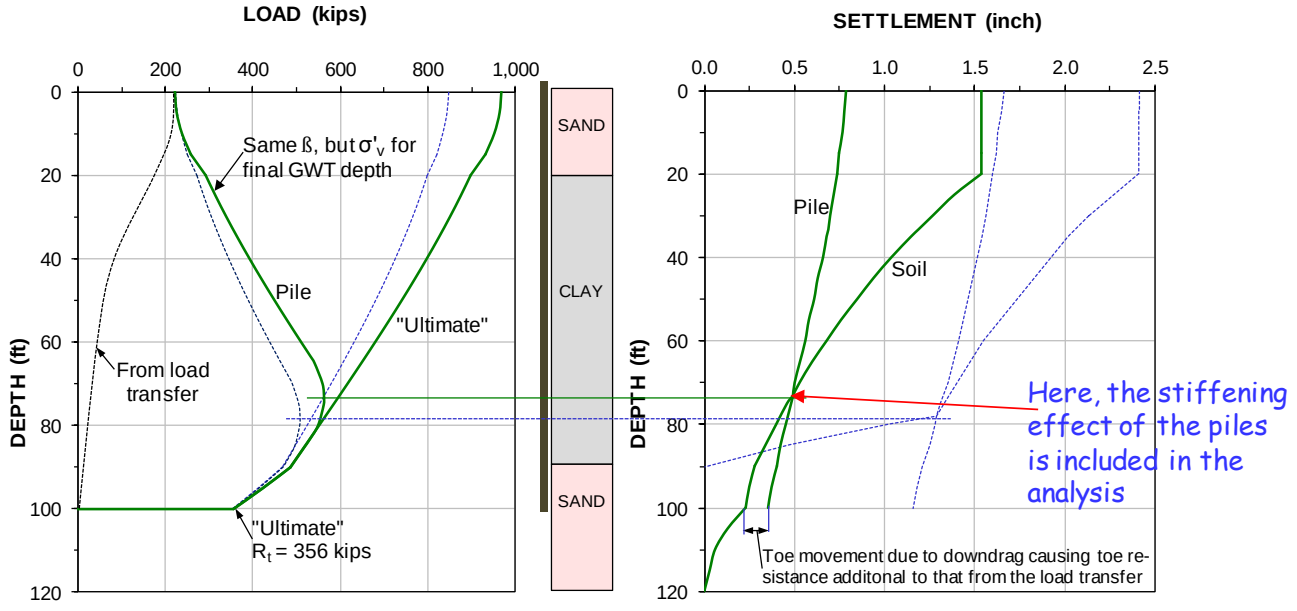


TOTAL STRESS AND EFFECTIVE STRESS LOAD AND RESISTANCE DISTRIBUTIONS

REPORTED SETTLEMENT DISTRIBUTION

for an equivalent raft placed at the N.P. with 2:1 stress distribution and disregarding the significant stiffening effect because of the piles. No settlement is assumed to occur in the dense sand.

The report states, “the GWT lowering occurred after pile installation and static load application”. This means that the effective stresses will increase and necessitates that the analysis be made using the beta-method. A recalculation for the long-term conditions with pile stiffening effect included results in the following.

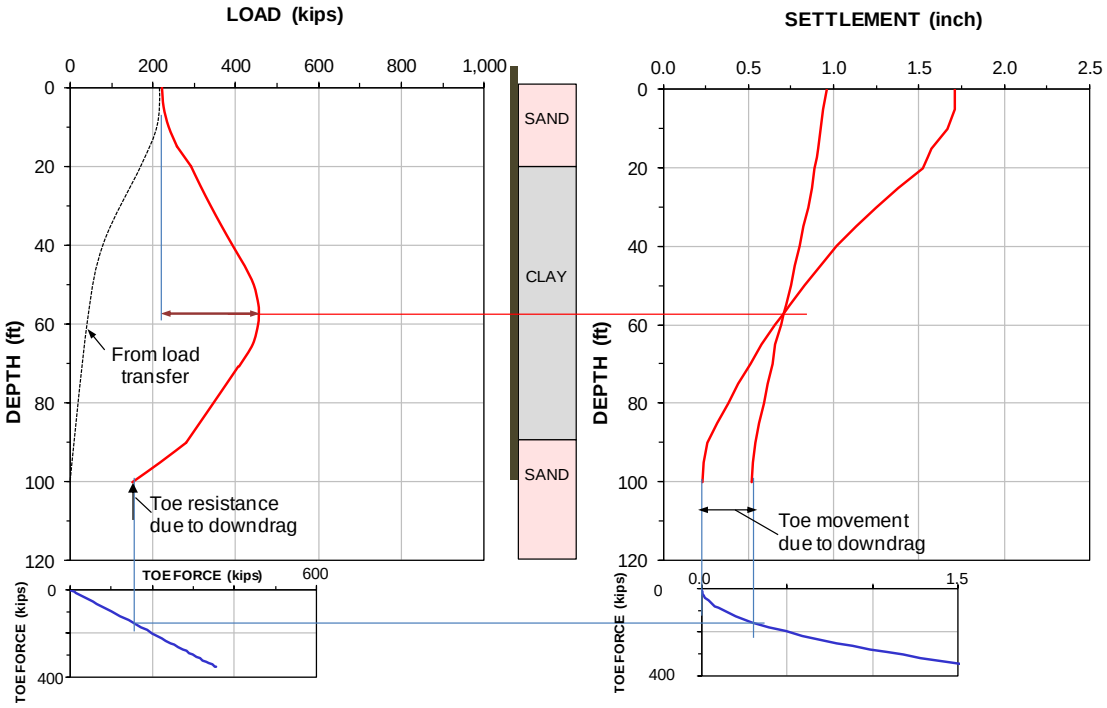


LOAD AND RESISTANCE DISTRIBUTIONS FOR INITIAL AND FINAL EFFECTIVE STRESS

SETTLEMENT DISTRIBUTION

for an equivalent raft placed at the pile toe depth with Boussinesq stress distribution and including settlement in the dense sand

The same toe resistance as that used in the report was applied. However, the toe movement and the toe force are not compatible. Movement compatibility is a key requirement of the unified design method. The results of an analysis ensuring compatibility between toe movement and toe force is shown in this figure.



Final set of adjustments is:

- a transition zone is applied
- calculations apply effective stress as opposed to total stress (though fitted to the total stress values of the report)
- the equivalent raft is placed at the pile toe (avoiding the need for imposing the pile stiffness)
- the stress distribution is by Boussinesq
- sand compressibility is included
- toe movement and toe force are compatible.

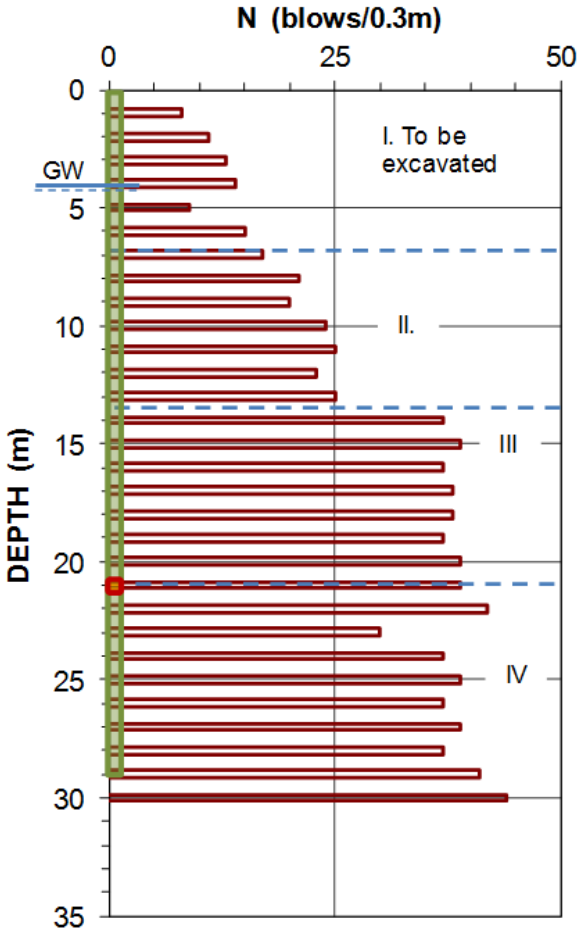
One aspect not included in the adjusted analysis is the spreading of load between the N.P. and the pile toe. Normally for pile groups, the size of the equivalent raft placed at pile toe should be increased beyond the actual pile cap footprint with a value equal to about 20 % times the distance between the N.P. and the pile toe, i.e., 5(V):1(H) load spreading. That is, the equivalent raft would be about 20+ ft wide. For a very small group, such as the subject one, this is of little consequence, even questionable if it would apply, so it was omitted it.

The adjustments resulted in a smaller calculated settlement (about 1.0 inch as opposed to about 1.6 inch). The primary observation is that in adapting the Fellenius unified method, the Corps of Engineers have realized and agree that the drag force must not be included in the capacity assessment of a piled foundation.

Example 12 - Analysis for placement of the bidirectional cell

Example 11 illustrates using UniPile to find the balance point for placing a bidirectional cell, that is, so as to ensure that the test will provide information on both upward and downward response of the pile to load. The pile is a 1.3 m diameter 29 m embedment bored pile constructed in the below soil profile, showing the density to be compact all through, although a boundary line appears to exist at 13.5 m depth. The borehole log states that the soils consist of a marine deposit of fine to medium sand. As unfortunately often is the case, neither water contents, soil bulk densities, nor results of grain size analysis are included with the borehole information. The groundwater table is located at 4 m depth.

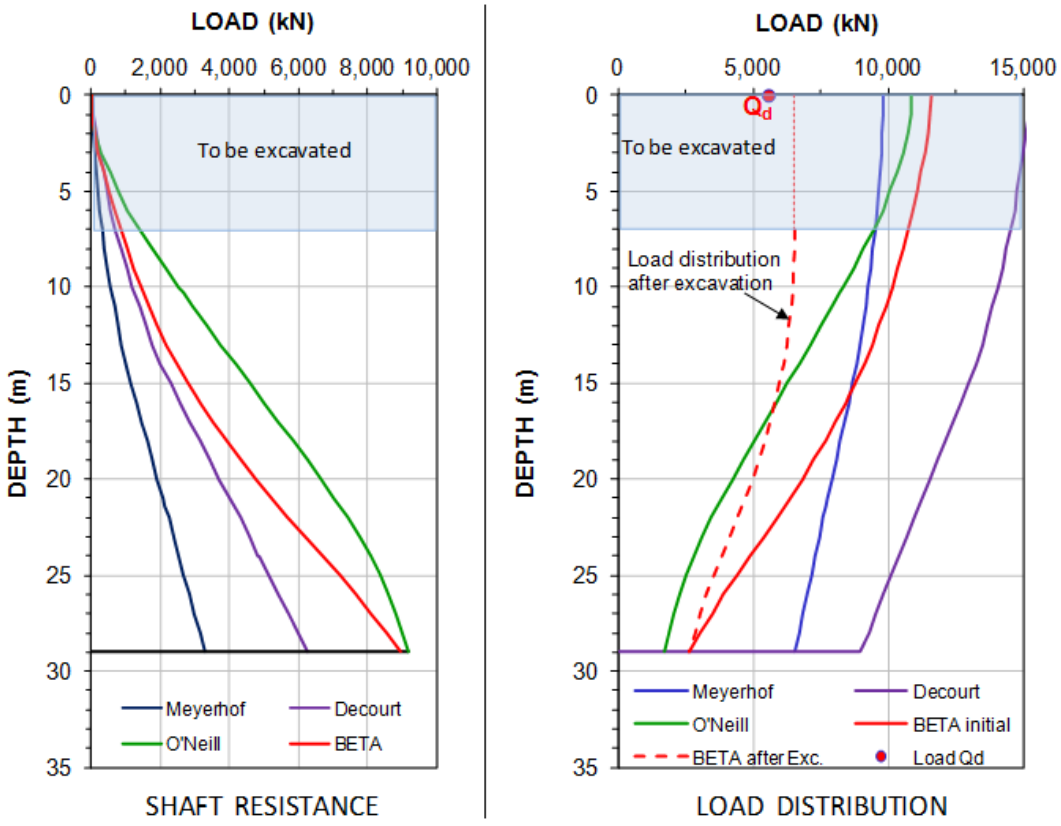
The pile will eventually support a building with a basement requiring an excavation to 7 m depth. The groundwater table will be permanently lowered to the 7 m excavation depth. The desired working load (all is dead load) is 5,500 kN.



The first step in designing a bidirectional test is to determine the best placement of the cell—the depth to the "balance point" or the "sweet point"—, which is where in the test, the cell load will, ideally, result in a downward cell movement of at least 30 mm and an upward cell movement (or pile head movement) of at least ≈10 mm. This requires calculating the expected load distribution for the maximum load (taken as the theoretical "ultimate" resistance of the pile). The available soil information is limited to the SPT N-indices and the soil descriptions. Having also, a CPTU-sounding would have been preferable, even instead of the N-indices.

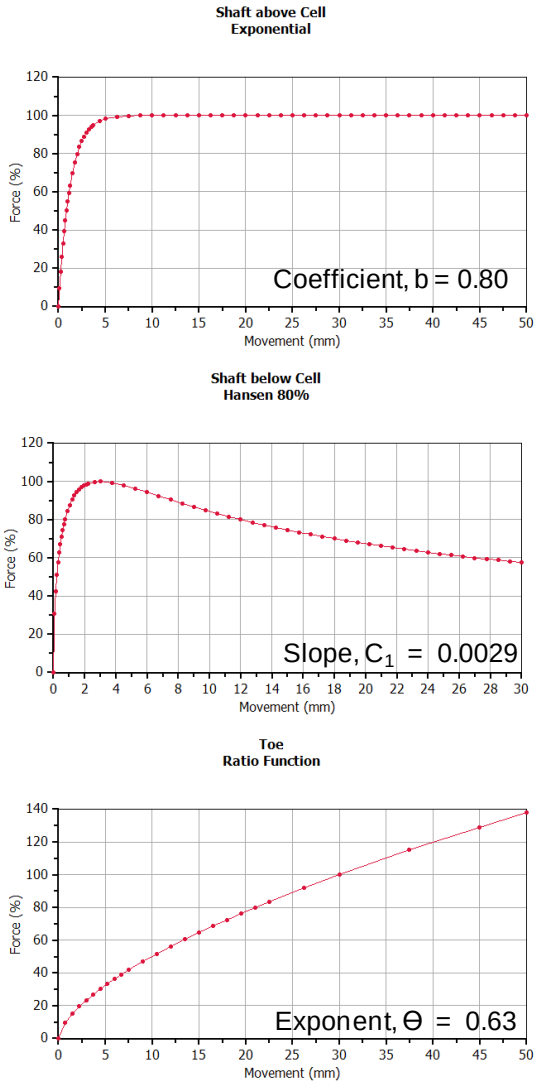
To establish the soil profile, the analysis starts with input of the soil layering, water table, and estimated soil densities along with the SPT-N-indices input. The N-indices allow the use of the SPT-methods proposed by Meyerhof, Decourt, and O'Neill. This notwithstanding that the SPT N-indices are not reliable as base for numerical input by any method unless the User has a solid knowledge of the limitations involved and prior experience to go by.

On executing the program for one SPT-N method at a time, the pile load distributions for the three methods are output, as shown in the below graphs. The output is separated on calculated shaft resistance and calculated load distribution. In this case, the difference between the methods pertain to the toe resistance values with the shaft resistance values more in agreement. The below figure shows the calculated shaft resistance distributions and load distribution. The curve labeled "BETA" is the distribution calculated in a per-best-judgment selected set of ß-coefficients for the for soil layers identified in the soil profile. The effective stress analysis is from this point on the main base for the continued analysis. The same coefficients have been applied to the conditions valid for the construction of the building after the excavation and a include 3-metre lowering of the groundwater table.

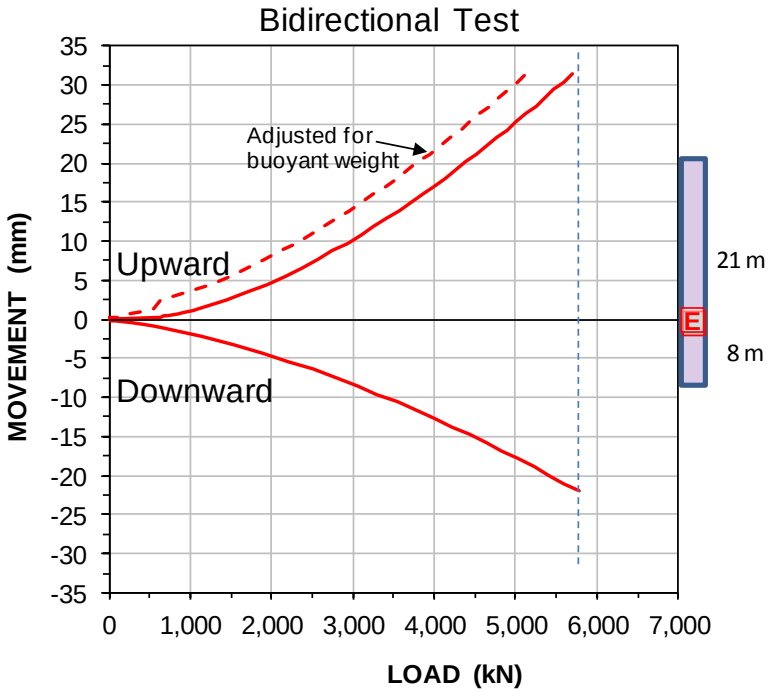


After having decided on a representative selection of ß-coefficients, representative t-z and q-z functions need to be chosen. This process requires deciding whether or not the shaft functions display strain hardening elastic plastic or strain softening. Moreover, common for the t-z functions is that to mobilize an ultimate shaft resistance requires a movement of a few millimetre, only. In contrast, the toe resistance does not develop an ultimate value. In practice, one still represents the ultimate toe resistance defined as the resistance mobilized at a specific toe movement—according to the Red Book a 30-movement is suitable for most cases. It is assumed that this movement will require a 2-MPa toe stress, which might be a bit optimistic for a bored pile in compact sand.

The t-z and q-z functions assumed for the analysis of the case are shown in the below figure. In Layers I through III, the stress-movement response for the pile elements is approximately elastic-plastic and follows the "Exponential Function". In Layer IV, the response is assumed to be strain softening as expressed by the "Hansen 80-% Function". The toe resistance is assumed to be according to the "Ratio Function" with an exponent of 0.63. (The 0.63-exponent means that a trebling of the toe movement results in a doubling of the toe resistance, a relation commonly observed in actual test).



The ideal location of the depth of the cell is at the depth of the neutral plane for no load at the pile head, which comes out as 21.9 m depth. A 21.0-m depth is input, and UniPile delivers the results as shown in the following graph. The solid lines are the output for a calculation simulating actual test results. The upward dashed line is the output for when the buoyant weight is subtracted from the calculation.

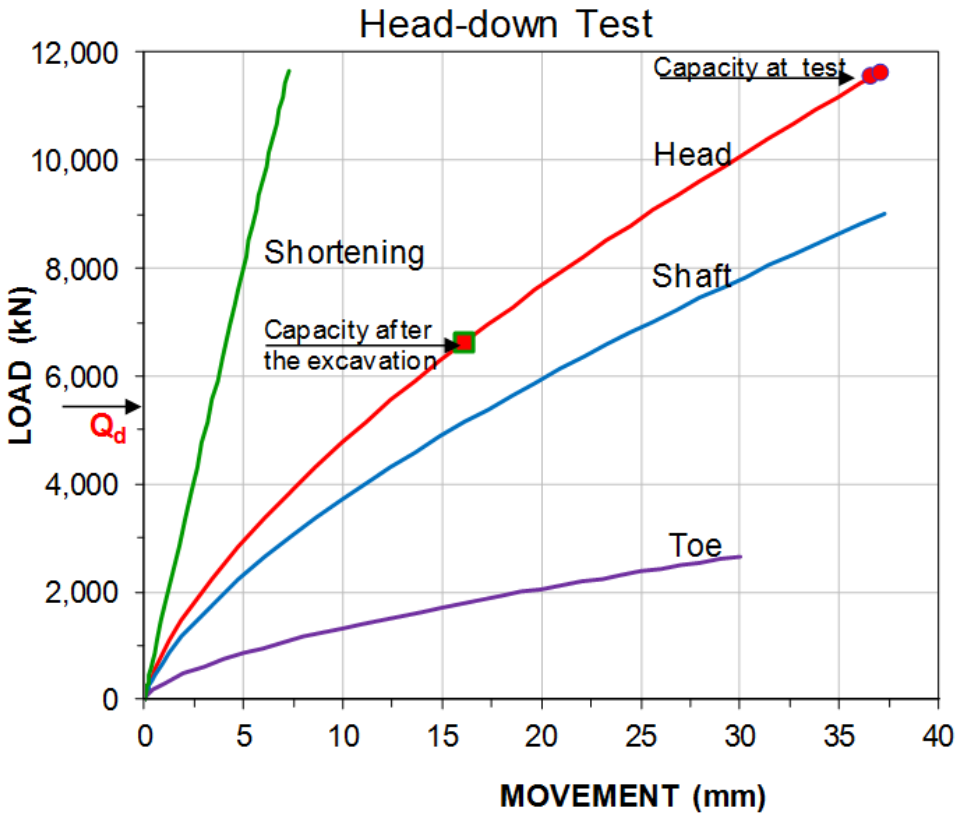


Note, most routine head-down static loading tests are only performed to a maximum or test load equal to twice the intended working load to be applied to the pile from the supported structure. It is unfortunate that this principle has been carried over to the bidirectional test inasmuch that the tests are terminated at the cell load equal to the working load (combines to a test load at the pile head of about twice the cell load). However, although the minimum approach is to design the bidirectional test so that the test can assuredly be performed to a cell load equal to the working load, but, then, when the test is performed, it should be continued to the maximum load possible.

The cell location is not critical for the bidirectional test. A cell location anywhere between 19 m and 23 m depths would have given a satisfactory result for the subject case. When designing a test for the actual placement of the cell, one should err on the deeper side placement. Based on the here calculated results, the design for this case should probably be best at a 23 m depth. Even 24-m depth might have worked, provided pile toe response had not been affected by toe disturbance and inadequate cleaning of the shaft bottom before concreting.

The equivalent head-down load-movement response can be calculated directly from the actual results of a bidirectional test with due consideration of the effect of pile stiffness, the fact that the head-down test engages the upper soil layers first, whereas the bidirectional test engaging them last, and that the bidirectional test is assisted by the water force acting on the pile at the cell level (See the Red book). To include these factors in a hand calculation of the results of the bidirectional test is time-consuming and can easily produce a pile-head load-movement curve for long piles that is a stiffer than the real curve would have been; an error on the non-conservative side. However, UniPile provides the means of doing a theoretical calculation that does consider all factors. It is relatively simple and fast to fit the measured upward and downward curves to the actual test results in a UniPile calculation of the bidirectional test. Once the fit is achieved, the UniPile head-down calculation then provides the Equivalent Head-down Test results.

Below is the Equivalent Head-down load-movement curves for the subject test simulation.



The Equivalent Head-down Load-movement results determined from the results of an actual bidirectional test include the pile toe load-movement, which a conventional static loading test does not provide without instrumentation. The pile head curve can be used for the User's preferred method of determining pile capacity. The capacity for the 30 mm pile toe movement is indicated.

Note that were the analysis and the bidirectional test performed for an actual case before the excavation was made, then, after the excavation is completed, the reduction of the effective overburden stress due to the excavation will have a much reduced the pile capacity and the pile may not be able to safely support the building. One of the advantages of a bidirectional test is that the test can be repeated after the excavation has taken place to verify the effect of the excavation.

EXAMPLES FROM FOUR PAPERS AT B.H. FELLENIUS WEB SITE

The UniPile program has been used by B.H. Fellenius in reporting on several case history papers. The papers are available for downloading from online at ww.Fellenius.net. We have placed a couple of UniPile files containing the analysis data of a few of the case histories amongst the example files, for anyone interested in dwelling on the analysis methods.

314 Sunrise City.Unipile5

314. Fellenius, B.H., and Nguyen, M.H., 2013. Large diameter long bored piles in the Mekong delta. International Journal of Case Histories, www.casehistories.geoengineer.org, 2(3) 196-207.

331 FITTED to test - Effective stress.Unipile5

331. Fellenius, B.H., 2014. An instrumented screwpile load test and connected pile-group load-settlement behavior. Discussion. Journal of Geo-Engineering Sciences, IOS Press, 1(2) 101 - 108.

341-DFI-EFFC Eurocode example.Unipile5

341. Fellenius, B.H., 2014. Piled foundation design as reflected in codes and standards. Proceedings of the DFI-EFFC International Conference on Piling and Deep Foundations, Stockholm, May 21-23, pp. 1013-1030.

342-Cobramseg Brazil CFA and 342-Cobramseg Meyerhof 1981 H800 - Soft Toe

342. Fellenius, B.H., 2014. Analysis of results from routine static loading tests with emphasis on the bidirectional test. Proceedings of the 17th Congress of the Brasiliero de Mecanica dos Solos e Egenharia, Comramseg, Goiania, Brazil, September 10 - 13, 22 p.